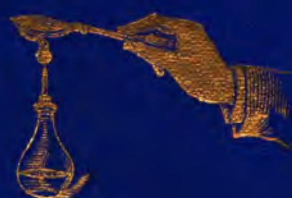

CHEMISTRY.

AN

EASY INTRODUCTION

TO

CHEMISTRY

EDITED BY THE REV.

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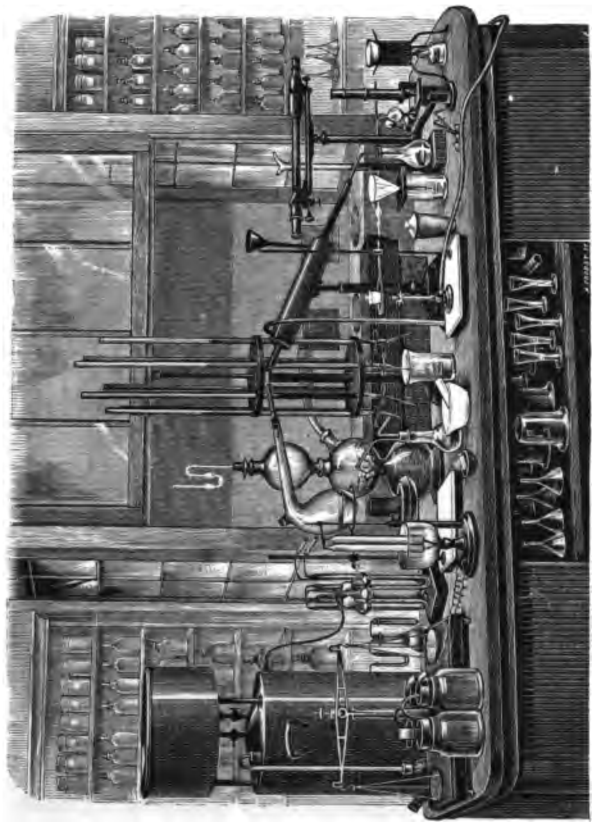
WITH NUMEROUS ILLUSTRATIONS

RIVINGTONS

London, Oxford, and Cambridge

1873

CHEMISTRY.



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CHAPTER I.

THE CHEMIST.

Chemistry. In this book you are to learn about chemistry. But what is chemistry? you may ask. I will try to explain, and I am sure that the more you learn, the more you will find how very much there is in it you would like to know.

The discoveries of chemists will surprise you. Perhaps you think each substance you see is all one thing. Chalk you think is chalk, and that is all. But the chemist has discovered that chalk is made of three things put together. One is a gas as light as air; in fact, it is a gas that forms part of the air you breathe. Another is carbon or charcoal. Yes, dark charcoal makes a part of white chalk; but the charcoal is not dark *now* because it is combined with other things. The third thing in chalk is a metal. So gas, charcoal, and metal, three things very unlike each other, make chalk.

Again, there is water. Water, simple water, *that* surely you will say, must be one thing. People used to think so—old philosophers (wise men) as well as common people and children. But chemists found out it was not one thing.

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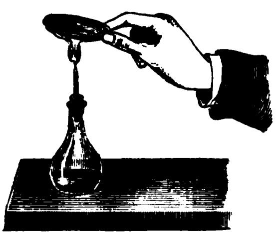
Water they found to be composed of the same gas that is in chalk, united with another gas with which they sometimes fill balloons. These two gases are continually uniting and forming water. In every fire you see, in all flames whether of wood, candle, gas or fluid, these two gases are busy, uniting to form water. You do not see the water, for as fast as it is formed it passes off into the air, and water in the air is so finely divided that you cannot see it, but you can catch it as it is formed in the flame, and so cause it to be seen. There are many ways in which you can do this. Here is one shown in Fig. 1. If a *cold* spoon, or a spoon with a little ice and salt in it, is held over ever so clear a flame, the finely-divided water as it passes from the flame is what chemists call *condensed*, and gathered upon the under side of the spoon. If you hold the spoon so high that soot is not deposited upon it, a large drop of water may be seen to hang from the bottom where you would think the spoon was hottest.

Fig. 1.



Perhaps you may have noticed that when a bright kettle of cold water is set on the fire, or over a gas flame, the outside of the kettle is not only covered with a dew, but sometimes drops of water trickle down. This water is being formed by these two gases.

But I will tell you how you can not only catch, but actually shut up the water, as you see in Fig. 2.

Here a candle is placed under a glass, and the water first makes the glass dim, but soon gathers so much as to trickle down its sides. You can try this experiment with any glass jar, but you must remember to put some little bits of wood under the edge, as you see in the figure. If you do not, the candle will soon go out, for reasons that I will explain to you in another chapter, and there will be but little water formed. As the outside of the glass must be cool, do not try this in a very warm room.

Fig. 2.

Water is *composed* of two gases. Now when the chemist takes water, and separates one of the gases from the other we say he *de-composes* the water. He does just the opposite of what is done in flame, for there the two gases *unite* and form water. So, when he separates the things that form chalk from each other, he *decomposes* the chalk.

In other parts of this book I shall tell you more particularly about these and many other wonderful things.

Perhaps you think you are too young to know anything about chemistry, and that only older persons can understand it. This is not so. There are many things in chemistry that you can understand as well as older people. I shall try to select such only as you will be interested in knowing, and leave the rest to be learned when you are older.

Chemistry is interesting because it tells about so many things you see every day. Perhaps you think that the chemist is only concerned with substances that have hard names, and with which you have nothing to do, but it is far otherwise. Many things that he can tell you about are very common. I have already spoken of chalk and water. The little I told you of their composition perhaps interests you, and you will be still more interested when told other particulars respecting them. Then there is the air we breathe—you would like to know about *that*. The chemist can tell you what part of the air is needful that we may live. You will be surprised to learn that some of it is continually becoming a part of your body, your flesh and bones, and that some of your body is all the time turning into gas, and flying off all around. But so it is, as shall by-and-by be shown.

Chemistry can tell why fires burn brightly. You will find that there is a great deal of chemistry in so common a thing as a candle. A most distinguished chemist (the late Michael Faraday) delivered six lectures to a young audience in London on the "Chemical History of a Candle," and they have been published, making a book of more than 200 pages.

Chemistry also tells what it is that makes bread rise, and how it is that bread nourishes the body; also how soaps are made, and why they cleanse clothes and other things; also how paints and dyes are mixed and employed.

About these and very many other common things chemistry can tell much of interest that will be of use in many periods of your life. You may now know more about

these and other subjects than the wisest people knew fifty years ago, for chemists have discovered much not then known.

You may have heard that chemists try experiments. In this book I shall describe experiments, many of which you can try for yourselves. You can try them with bottles and tubes that cost very little money, and by exercising a little contrivance you can try many of them with what is at your own homes.

But you need not do even this to be interested in chemistry, because there are things that illustrate the subject continually happening before you. There are experiments, so to say, going on not only around, but within you; and you have only to look and chemistry will be found everywhere in action.

CHAPTER II.

OXYGEN.

Oxygen. That is a hard word, you will say. Why hard? Simply because it is new, and you do not understand what it means. When I have told you what oxygen is, and related some interesting facts about it, the word will be as easy as any other of the same length of which you know the meaning. The names of your acquaintances would be hard words if they were not the names of those you know. Now I hope to make you as well acquainted with oxygen as you are with any of your friends, and then it will seem quite as easy a name as Joseph, or Caroline, or Elizabeth. Many words in use every day are much longer than oxygen, such as "amusement," "temperature," "velocity," &c.; but they are easy when you are familiar with them, and know what they mean. So, when you have read this book, oxygen and other terms now new, and therefore hard, will be easy, because you will know their meaning.

Though not yet acquainted with oxygen, you have a great deal to do with it. Indeed, you could not have done without it at any moment since you were born. Every time you draw a breath some of it is taken into your lungs, for it is in the air. If what there is of it in the air should be taken out, you would die as quickly as you would under water.

This oxygen is nourishment to the body. True it does

not go into the stomach, but still it is quite as necessary as the food you swallow. It goes into the lungs, which must have it or death would result.

You may live for days without food being put into the stomach ; but lung-food must be had every minute.

That which goes into the lungs helps to make the solid part of the body—bones, muscles, skin, &c. But when it goes in it is a gas, and not a solid: there are many kinds of gases. The air you breathe is a mixture of gases. The gas that we burn is different from that in air. You see it burning when you see a flame, whether from wood, coals, candles or lamps. Oil or tallow is changed into gas before it burns. Flame is burning gas. When wood or coal is burnt, all except the ashes that are left goes into the air, and generally manifests itself by a flame.

Most gases have no colour, and they can be looked through as if through glass. You are always looking through gases, for the air is a mixture of three gases. You cannot see air, neither can you see gas that has no colour. For example, if a gas-tap be left open and the gas not lighted, you may not see, but you can smell the gas coming out. Colourless gases are said to be perfectly *transparent*, like clear glass, because objects are seen or *appear through* them, *trans* being the Latin for *through*.

I shall tell you presently about many different gases, but *now* more particularly of oxygen.

Oxygen is a part of almost everything you see. It forms a large part of all the water in the world. As I have already told you, it is in the skin, muscles and bones, and is a most

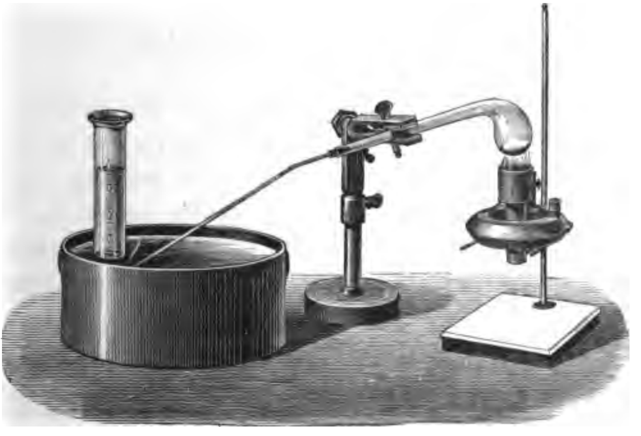
important part of the blood that runs in the veins and arteries. The ground beneath our feet and even solid rocks are made in part of oxygen. This gas is very abundant, and occurs to a greater extent in nature than any other substance.

It may seem strange that gas can make part of such solids as flesh and bone. But in winter a liquid becomes solid, for ice is solid water. Now this same water, that is sometimes liquid and sometimes solid, is sometimes also a gas. There is always water even in dry air; and as in clear dry air no water is to be seen, the water must be as *thin* as air itself. It is no more strange that oxygen gas can become part of a solid, than that water can be turned into ice.

Oxygen gas can be separated from some of the substances with which it is united, and so can be had by itself. Chemists commonly use for this purpose a crystalline substance. What that is I will not tell you now, but shall do so in another part of this book (page 97), when you can understand it better than at present. This powder is placed in a glass vessel, called a *retort*, and heated by a spirit-lamp, as represented in Fig. 3, or by a gas flame. Oxygen, separated from the powder by heat, passes over and bubbles up from a pipe in the beak of a retort, as it is called, which you see dips under water in a large tin vessel. There is over the pipe a glass vessel, called a *receiver*—a wide-mouthed bottle with its open end downwards answers very well. This receiver is filled with water by being put under water in the large tin vessel. It may then be turned with its mouth downwards, and partly raised out of the water. As the pipe from the retort is under the mouth of the jar, gas

being lighter than water goes up in bubbles, and takes the place of the water in the upper part of the receiver, which

Fig. 3.



may thus be filled with oxygen gas. In collecting this gas, the first bubbles must not be caught, for the air in the retort must be driven out, because we do not want to catch air. Let that go, and catch the gas that comes afterwards.

The tin or earthenware vessel in Fig. 3 is called a *pneumatic trough;* in it is a shelf, a little under the water. Receivers stand on this shelf. The beak of the retort or pipe is near the edge of the shelf, and the receiver is filled by placing it just over the open end. Or there may be an opening in the shelf, through which the gas may be discharged into the receiver.

A jar of gas is easily taken from the vessel when wanted for experiments. Your own ingenuity may contrive several

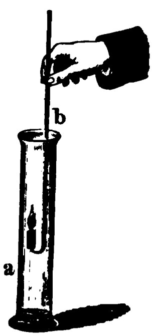
ways. One is to slip a small plate or a piece of window-glass under the mouth of the jar before it is removed. It may then be taken from the trough of water, and placed upright on a table, as (a), Fig. 5.

There are many beautiful experiments that can be tried with oxygen. I will tell you some of them.

Put a lighted wax taper fixed to the end of a piece of bent wire, as shown in Fig. 4, into a jar of oxygen (a), as in Fig. 5.

Fig. 4.

Fig. 5.



It will burn with dazzling brightness, and be rapidly consumed. The reason is this. It is the oxygen in the air that makes the taper burn at all. Of course, the more oxygen gets to the taper the brighter it will burn. Now only about one fifth of the air is oxygen, and so the taper in the jar (a) will burn five times as fast and as brightly as in common air.

Some substances which do not burn brightly or with flame in common air may become bright and flaming in oxygen gas. If you watch charcoal burning in the ordinary fireplace, it appears of a dull red heat—no life in it—neither sparks nor flame. Put such a piece of dull charcoal in this gas, then it will have a supply of oxygen five times as abundant as it had before. The consequence is that what may be called its activity will be increased, and this is manifested by the great number of bright sparks thrown all around and by the rapid consumption of the piece of charcoal.

There is no substance that makes so brilliant a light in burning in oxygen as phosphorus. A very thick white smoke arises, which is most brilliantly illuminated.

Fig. 6.

If sulphur be burned in oxygen gas, the smoke has a most beautiful blue colour; and is arranged in a very singular way. It goes up straight in the middle of the jar, and then falls in curious rings down the sides.

Fig. 7.

The mode in which you may arrange a taper or charcoal or phosphorus or sulphur for burning in oxygen is shown in Figs. 6 and 7. A glass jar is first filled with oxygen in the way shown in Fig. 3, page 9. The substance to be burned is placed at the end of a wire, which is prevented from falling by being passed through a piece of card, as seen in Fig. 7. Or a bell glass may be placed over the substance, as in Fig. 6.

There are some substances which most people think cannot burn, that do burn very readily in oxygen. Iron is one of these. If you take a piece of very fine iron or steel wire, and twist it as you see in Fig. 8, you can make a splendid fire with it in the oxygen. But how will you manage it? You cannot set it on fire in the air, and then introduce it into the oxygen, as is done with phosphorus, charcoal, etc. It is managed in this way. The end of the fine wire is dipped in sulphur, or has a bit of something which will burn in common air fastened to it, as charcoal. You light this substance, and introduce the wire into the jar of oxygen. The substance on the end of the wire in burning sets fire to the wire itself, and then sparks fly most merrily.

Fig. 8.

CHAPTER III.

NITROGEN.

Nitrogen. In five gallons of air there are about four gallons of a gas called nitrogen, and about one gallon of oxygen.

Nitrogen is very different, in some respects, from oxygen. Nothing will burn in nitrogen. Suppose you have two bottles or receivers in one of which is oxygen and in the other nitrogen. If a lighted candle be put into the one of oxygen, it will, you know, burn brighter than in air. But if taken out of oxygen, and put into nitrogen, it will not burn. Even phosphorus will not burn in nitrogen. So, if all the oxygen should be taken from the air every fire would go out.

Besides this, no animal can live in nitrogen gas. Therefore, if the oxygen should be taken out of the air, all animals would die, just as all fires would be extinguished.

Although animals cannot live if they breathed only pure nitrogen, yet this gas enters very largely into the composition of the flesh of all animals. It also forms a large part of the vegetable substances that are used for food. It becomes part of the flesh of animals in consequence of the food they eat and not from the air they breathe. If in the food there was no nitrogen, the body could not be nourished. In a chapter near the end of the book you may read more on this subject.

A fire or flame when placed in nitrogen goes out because there is no oxygen. Put only a little oxygen into the nitrogen, and the candle will burn; for it does burn well in a mixture of oxygen and nitrogen, that is, in common air, in which there is four times as much nitrogen as oxygen.

So, nitrogen does not act as a poison to an animal; for there is going into the lungs of all animals four times as much nitrogen as oxygen.

Perhaps you are already asking of what use then, is nitrogen in air, since it does not make any thing burn, or keep any thing alive? I will tell you.

Suppose that the air were all oxygen instead of being a mixture of oxygen and nitrogen. What would happen? Call to mind the experiments in which different things were burned in oxygen. Our fires would burn very brightly. This would sometimes be pleasant. We should not be troubled with dull fires and dim lights. It would be one of the easiest things to kindle a fire. But on the other hand there would be great inconvenience and danger from so much oxygen. Things would burn very fast. They would be too ready to take fire. We should have things taking fire much oftener than now; and it would be very hard to put such fires out. Towns and cities would be often burned. Sparks from engines of railway trains would be continually setting fire to bridges or fences, and candles would do the same to furniture and houses. We should have to be much more careful about fire than we now are.

Beside all this, if the air were wholly oxygen it would be injurious to animals. It would be too heating, too stimu-

lating. With so much oxygen entering our lungs we should be as hot as we are after violent exercise. This would make us very uncomfortable. We should be always fanning ourselves, drinking cold water, and seeking cold air. Inflammations and fevers might be produced, and we could not live long in this way.

For such reasons as these our Creator may have given us oxygen mixed with so much nitrogen. This mixing is what we often do. Milk is mixed with tea and coffee, flavourings are mingled with soups: and articles not pleasant are made pleasant. Thus oxygen being mixed with nitrogen we may take it without harm.

Nitrogen, you see, goes every where with the lively oxygen, and as it were keeps it in check. It however unites with many substances. I will now give only two examples. Nitrogen unites with hydrogen and oxygen, as you will see in the next chapter, to form a most powerful acid—*aqua fortis*. It is also one of the two ingredients of ammonia or hartshorn, which when smelt so tingles the nose.

Fig. 9.

You can get nitrogen from the air by a very pretty experiment. A large basin or trough (as in Fig. 9), a good-sized glass jar, a flat cork smaller than the open end of the jar, some powdered chalk, and a bit of phosphorus, are all that are needed.

You may wish to know how much phosphorus to use. If the jar holds a pint, a piece of phosphorus the size of a large pea will be needed. Phosphorus takes fire so easily that great caution is required in handling it.

Fill the basin with water; hollow out a little place on the cork and sprinkle some chalk into it; place the phosphorus on the chalk, and then set the cork on the water. Light the phosphorus by touching it with a hot wire, and put the jar over it with its edge in the water. There is in the jar a mixture of oxygen and nitrogen, that is, air. Then there is burning phosphorus. Now the phosphorus burns because oxygen is there. If there were nothing but nitrogen in the jar it would not burn. Watch the experiment, and you will soon see that the phosphorus burns rather dimly, and at length goes out, although there may be a large quantity left on the chalk. Why is this? It is because the oxygen is all consumed, and nothing remains in the jar but nitrogen.

Fig. 10.

You see the cork rises in the jar. Why? That part of the air in the jar which is oxygen is used, and the water and cork fill this room. If you take what is called a *test tube*—that is, a little glass vessel about the size of your finger—and arrange the experiment as shown in Fig. 10, you may measure the height to which the floating cork rises, and you will thus find how much oxygen has been in the air in the tube.

But what has become of the oxygen? It is not lost in the burning. It united with the phosphorus, and they together make the white smoke which arises when phosphorus is burned in oxygen as represented in Fig. 6. This smoke easily dissolves in the water, and in so doing forms what is called phosphoric acid. It soon disappears, and nitrogen is left alone in the jar.

CHAPTER IV.

NITRIC ACID, AQUA FORTIS, AND LAUGHING GAS.

NITRIC ACID. In air, as you have seen, oxygen and nitrogen are only *mixed* together. The oxygen is diffused through the nitrogen as milk is diffused through tea when they are mixed. But oxygen and nitrogen can be united so as to form *compounds* having properties very different from those of the mixture we call air. This act of uniting is called *chemical combination.*

By *chemical combination* is meant uniting in such a way that the substances cannot by any simple means be separated. Indeed there are changes in the combining substances which cause the character of the compound to be very different from what might have been expected. In the experiment described on page 16 with Fig. 10, you were able to separate oxygen from nitrogen. In that case the two were said to be *mixed.* When however, in some way unknown to us, these gases unite with hydrogen as in nitric acid or aqua fortis they cannot be so simply separated, and the result of the union is said to be a *chemical compound.*

One of these compounds is *nitric acid,* also called aqua fortis, which is Latin for *strong water,* because it is a very powerful acid. It will destroy cloth, and even flesh, if

dropped upon them. How strange that such a biting acid is composed of two gases so quietly going into our lungs every time we breathe!

Although these gases mix so thoroughly in the air, yet they do not then unite to form this acid. It is very difficult to make them unite. All the tossing about which the air gets in winds and whirlwinds will not do it. Air is sometimes greatly heated, but the heat of the hottest furnace cannot cause the oxygen and nitrogen of the air to unite and form a chemical compound. A flash of lightning will make them unite so as to form nitric acid; but there is very little made thus. This little, however, being carried down with the rain-drops, is of use to the farmer and gardener in promoting the growth of plants.

There is another compound of these gases named *nitrous oxide* of a very different character from nitric acid. It is in the form of a gas. It can be breathed and does not irritate the lungs. It produces, however, when diluted with air, a very singular effect upon the system, under certain circumstances, making the person who breathes it very joyous and excitable; hence it is called *laughing gas.* If, however, breathed without any mixture of air, the person seems to fall asleep. For the short time this state lasts the person does not feel pain. Teeth may be taken out and operations performed by doctors, and the patient not feel them.

Now in this gas, only oxygen and nitrogen enter; they are not mixed, as in air, but they are a *chemical compound.*

Observe how these two compounds differ. One, nitric acid, is a liquid which stains and corrodes, that is, eats

away gradually. The other, nitrous oxide, is a gas, soft, mild, and pleasant to breathe.

The reason of this difference is in the proportions of the ingredients. Nitric acid has more oxygen in it than the other gas has—just five times as much; that is, to every pound of nitrogen there is five times as much oxygen in nitric acid as there is in nitrous oxide.

Suppose that oxygen and nitrogen in air formed *chemical compounds.* What would happen? Suppose, for example, that these gases should unite in air and make a large quantity of laughing gas. In whatever country this happened the people would play strange pranks.

Or suppose that these gases should unite to form nitric acid in the air. It would destroy the life of every animal and every plant in the world.

If the nitrogen and oxygen now in your lungs should suddenly unite to form nitric acid, you would probably die.

But the Creator has so made these gases that they do not form a *chemical compound* when simply mixed. When, at the Creation, He pronounced all His works to be "very good," He meant the air as well as other things. It is good—very good—for all the purposes for which it is wanted.

God has made some things so that they unite very readily. Thus, in the experiments in which phosphorus was burned, it combined with oxygen and formed *phosphoric acid.* Now if phosphorus were diffused through air as nitrogen is, it would not do to have it combining

so easily with oxygen. But there is none in air, and it is present only in those places where it will not do harm. This, and other things I shall tell you about, show that the Creator fits every thing exactly for the place in which it is to be, the company it is to keep, and the thing it is to do.

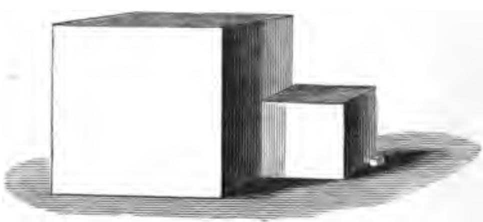
There are three other chemical compounds of oxygen and nitrogen, making, in all, five compounds, which differ only in the relative quantities of oxygen and nitrogen combined.

CHAPTER V.

CARBON.

Carbon. Thus far I have spoken of two gases in the mixture that we call air. But there is a third gas, in very small quantity, called *carbonic acid*, or *carbonic acid gas.* There is only one gallon of this gas in every 2500 gallons of air.

Fig. 11.



The proportions of the three gases may be illustrated by Fig. 11. The largest cube, or square box, represents the bulk or quantity of *nitrogen*, the next the bulk or quantity of *oxygen*, and the very little cube the bulk or quantity of *carbonic gas.* Although there is so small a quantity of this gas in the air, it has a very important influence, as you will soon see.

Carbonic gas differs from oxygen and nitrogen in being composed of *two* things. Oxygen is one thing, and so is nitrogen. Neither of them, as far as our present knowledge goes, can be divided, and they are called *elements,* or elemen-

tary substances. But carbonic acid is not an element, but a *compound*, for it is made of two things *united in one*. Observe, these two things are not *mixed* as nitrogen and oxygen are in air, but they are *combined* to make one thing—as much as if it were really an element. The two elements which compose carbonic gas are your life-exciting friend, oxygen, and another I will now introduce to your acquaintance—carbon.

Carbon appears in various forms, but the most common is that of charcoal. It is for this reason that the two names, charcoal and carbon, are ordinarily used by chemists as meaning the same thing. The various kinds of coal that we burn are mostly carbon. Plumbago, or black lead as it is called, is a very pure form of carbon. It is this which is used in lead-pencils. The name *black lead* is very improper, for there is not a particle of lead in this substance. It is wholly carbon, with the exception of a very very little iron generally present.

In the diamond we have carbon perfectly pure and beautifully crystallized. How strange that this most costly and brilliant of gems should be made of the same material with common dull and black coal or charcoal! But so it is. And yet no man has been able to change charcoal into diamonds. The Creator alone knows how diamonds are made.

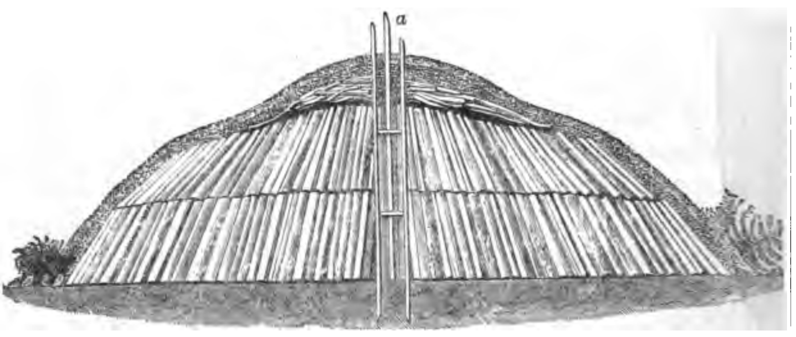
The diamond is perhaps the hardest substance in the world. You cannot scratch a diamond with any thing else; and in preparing a diamond to be "set," that is, fixed as jewels are in brooches, it is ground with the powder of diamonds. With a small diamond thus "set" in the end of a wooden pencil the glazier cuts glass.

All different forms of carbon can be burned. Most of them burn in common air; but *black lead* and the *diamond* will not. To burn them you must do so in oxygen *alone*, without any nitrogen.

Observe what comes from burning carbon. You remember that on page 17 I told you that when phosphorus is burned it unites with the oxygen of the air, making phosphoric acid. So, when carbon burns it unites with oxygen and forms carbonic acid gas. This gas is formed when we burn a diamond in oxygen, as well as when we burn common charcoal. It is rather an expensive experiment to burn a diamond, but it has often been performed.

The charcoal we use is, you know, made from wood. It is wood partly burned. It is made by burning wood in a

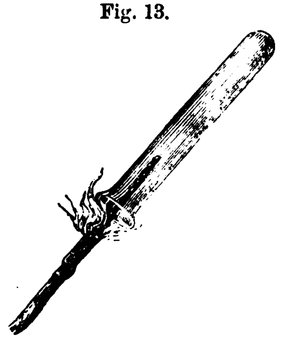
Fig. 12.



heap, covered up with turf. There are some small openings left above and below, so that a *little* air can circulate among the wood, and thus keep up a smothered burning.

The explanation is this. Wood is composed of carbon, united with other things. Now we want to get the carbon by itself. This we do by so burning wood as just to drive off into the air these other substances that are with the carbon in the wood. Some of the carbon is lost in this burning, for oxygen unites with it, and they fly off as carbonic gas. Most of the carbon remains, and we have it as charcoal. In making charcoal it is necessary to take great care not to admit too much air, lest the carbon that we require should be consumed by combining with the oxygen of the air and passing away as carbonic gas. As there is always water even in wood that seems very dry, this is driven off by the heat, and mingles with the smoke.

Fig. 13.



You can readily make charcoal in a small way. Take a test tube, Fig. 13, and hold a burning slip of wood in it. The tube prevents air from getting freely to the wood, so causing a *smothered* burning, and thus a slender piece of charcoal is produced.

Coal is almost wholly carbon. It differs from charcoal in being very solid. It is supposed that all the coal got out of coal-mines was once wood. How, then, did it become coal? Man can not make such coal from wood; but the Creator can do what man can not.

Soot is mostly carbon. It forms in the chimney thus: coal and wood in burning unite their carbon with oxygen

forming carbonic gas, which flies off—this gas you cannot see any more than you can air, but the smoke of the fire you can see, so that there must be something in it besides carbonic gas. What you see is made up of fine particles of carbon, which are thrown off from the burning coal or wood and fly up the chimney not being changed into carbonic gas. Many such particles lodge on the sides of the chimney and are called soot.

When a flame smokes, the smoke is made up of little particles of carbon, for there is carbon in gas and oil as well as in wood. The reason it smokes is that there is more carbon than is sufficient to unite with the oxygen that comes to it. If oxygen came to the flame faster, it would stop the smoking; for then there would be oxygen enough to turn all the carbon into carbonic gas. So too, smoking would stop if you should put the flame into oxygen gas. There would in that case be five times as much oxygen around the flame as there is when the flame is in air.

Lampblack, so much used in painting, is a kind of charcoal. It is made by letting the smoke of burning pitch or resin into a chamber lined with leather. The lampblack collects on the leathern sides of the chamber.

There is much carbon in many different things that we see. There is carbon even in chalk and marble. It is *chemically* combined in these with oxygen and lime, so that it does not show itself as carbon any more than it does in carbonic gas. It is in egg-shells, oyster-shells and all shells. It is in all wood, and makes an important part of leaves, flowers, fruit, and, indeed, of most vegetable

substances. The bodies of all animals have carbon as one of their principal ingredients. But it does not show itself as carbon any more than it does in white chalk and marble. It is, as it were, hidden by being *chemically* combined with other things. By separating it from these, it can be brought from its concealment and shown as carbon.

CHAPTER VI.

CARBONIC ACID GAS.

Carbonic acid gas, or Carbonic gas, as you learned in the previous chapter, is composed of *carbon* and the gas *oxygen.* The carbon is no longer solid, but united with a gas to form a gas; and the gas thus formed unites with many substances. For example, in chalk and marble we have this gas combined with lime.

There is a gas called carbonic oxide gas, but of this we are not going to write at present. On a future day you may learn of this and other gases not named in the present book.

Now we can obtain carbonic acid gas from either chalk or marble, by using something which will take away the lime. An acid called *muriatic* or *hydrochloric acid* will do this, because it has a greater affinity for lime than carbonic acid has. If we pour some of this acid into a glass vessel, and drop in pieces of chalk or marble, the carbonic acid gas separates from the lime. An effervescence occurs. This is caused by the gas being set free from the chalk as the hydrochloric acid takes lime from it. The gas rises, and pushing out the air, fills the glass vessel.

You will want to know how much hydrochloric acid and chalk you need in making the gas. If your glass jar holds a quart, pour into it two teaspoonfuls of the acid. Then drop

in little bits of chalk till effervescence ceases. Thus you get the jar full of carbonic acid gas, the muriatic acid and lime being united in the bottom of the jar.

This is commonly spoken of as *making* the gas; the expression is hardly a proper one. The gas is not *made;* it is united with lime in the chalk, and we only separate it by using hydrochloric acid to take lime away.

But there are ways of *actually making* this gas. For example, when we burn charcoal in a jar of oxygen, as represented in Fig. 7, the carbon unites with the oxygen in burning, and we have in the jar carbonic acid gas. Here we *make* the gas, for carbon unites with the oxygen, and thus forms it.

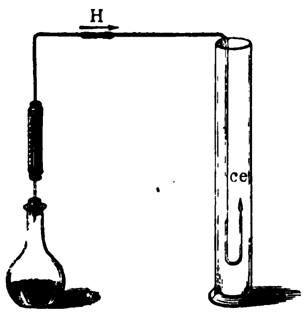
So also, if we burn charcoal in common air. In such case we do not get carbonic gas alone, but it has a large quantity of nitrogen mingled with it; you can tell how much, since you know that there are four gallons of nitrogen in five gallons of air.

Whenever, in fact, you set fire to wood or a candle or rag or paper you *manufacture* carbonic acid gas. There is carbon in all these, and in burning it unites with the oxygen of the air and forms carbonic acid gas.

For most of the experiments that we want to try with carbonic gas, it answers to obtain the gas in the way that I first mentioned on page 28; but for some experiments it will not do to have anything left in the bottom of the jar. In that case the gas must be made in a retort or a flask, and so pass out and be collected in jars, as we obtain oxygen gas. Or, we can obtain it in the way represented in

Fig. 14. Here, a flask contains chalk and muriatic acid.

Fig. 14.



A bent tube at one end passes through the cork, and the other end nearly touches the bottom of the jar in which the gas is to be collected. Now observe the operation. There is air in the flask and jar. This is driven out by the gas as it forms. This gas is heavier than air, and so the air very readily passes out, and leaves the jar full of gas. If you wish you may use two pieces of bent tube, connecting them with a little piece of india-rubber pipe, as at H. The thick tube just above the flask is for drying the gas. You will understand it better at a future day.

Let us look, now, at some of the qualities of carbonic acid gas. It has no colour, and is transparent. In these respects it is like oxygen and nitrogen. It has a faint smell and a slightly acid taste.

Ordinary combustibles do not burn in this gas. A candle lowered into a jar of it will be extinguished. A very pretty experiment is sometimes tried. We have two jars, one full of oxygen, and the other of carbonic acid gas. If a candle be lowered into a jar of carbonic gas it goes out. If now, it be instantly put into oxygen the spark on the wick lights at once into a bright flame, and so we can put out and relight the candle several times.

Why does the candle go out in the carbonic acid gas?

Because no oxygen is there to make it burn. But perhaps you will say that oxygen *is* there, for carbonic acid is composed of oxygen and carbon. True; but the oxygen is not there as oxygen, for it is combined with the carbon so as to make something entirely different. The union is a close one. The carbon clings as we may say to the oxygen, and will not let it go to the burning candle.

As ordinary combustibles cannot burn in this gas, so animals cannot live in it. I have told you that there is a little of this gas in common air; it is so very little that it does no harm to us and other animals.

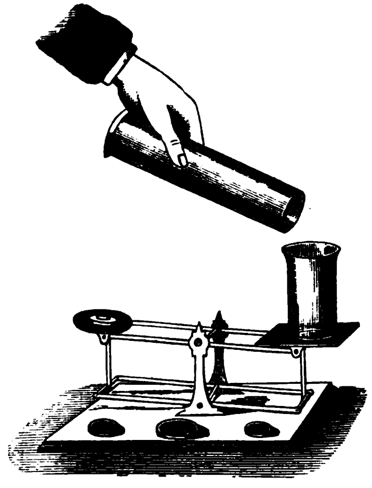
Carbonic gas is much heavier than air. You can therefore pour it, like water, from one vessel into another. Of course the vessel into which you pour it is full of air. What becomes, then, of the air? It rises and goes out of the vessel, just as oil would if you poured water into a vessel filled with oil.

Fig. 15.

Suppose, as in Fig. 15, you were to place for example a lighted taper in a jar, B, of common air, and you pour carbonic gas from a jar, A, as you see there; the gas will go down in the jar B, forcing up the air, and when it reaches the flame the light will be extinguished.

In Fig. 16 is represented a very pretty experiment, showing that this gas is heavier than air. First, balance a jar with a weight. I say *balance* a jar. Is that exactly correct? Is there not something in the jar? "No," you will perhaps say, "it is empty." But think a moment. That jar is full of something, and that something has weight. It is full of air. We have balanced, then, a jar full of air. Now if, as represented, carbonic acid gas be poured into the jar on the scales, the jar will descend and the weight will rise. Why? Because there is now a gas in the jar that is heavier than air.

Fig. 16.

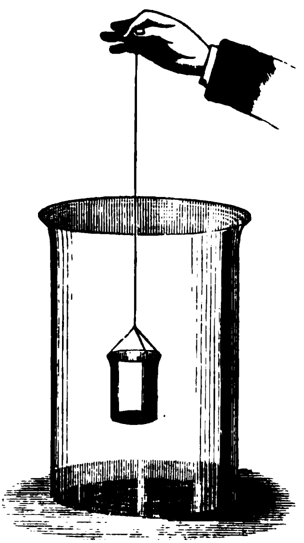


If you have a jar filled with this gas, you can take it out with a little bucket, as seen in Fig. 17. As you take one bucketful after another out, it can be poured away as water; and air will take the place of the gas as fast as it is removed.

If a soap-bubble fall into a jar of carbonic acid gas, it will not go to the bottom as it would if the jar were full of air. It will descend a little into the jar, and then ascend and remain in its open mouth. Why is this? The air that is blown into the bubble is lighter than the gas in the jar,

and the bubble therefore floats on the gas as a boat on water. If the jar be only half full of the gas, air filling therefore the upper half, the bubble will stop when half way down.

Fig. 17.



Another very entertaining experiment, showing that carbonic acid gas is heavier than air, can easily be made. Place four or five lighted candles in a row. If this gas is poured upon them, one after another will be put out.

This gas has been used to put out fire. Some years ago a coal-mine in Scotland was on fire, and could not be extinguished by any common means. There was danger that a large amount of coal would be wasted if the fire continued. A Mr. Gurney made a quantity of carbonic acid gas in a part of the mine where it would sink down to the fire and put it out.

As carbonic acid gas is so heavy it remains below air wherever it collects. Sometimes it is produced in wells, remaining at the bottom. Suppose a man goes down into such a well; he will have no difficulty at first, because the air is good; that is, it has enough of oxygen in it and not too much of carbonic acid. But when he is near the bottom, where the carbonic acid gas has accumulated he gasps for breath and falls. Perhaps some one, not understanding the

cause of the trouble, goes down to relieve the man and he also falls senseless. In this way many lives have been lost.

Now how can we find out whether this gas has collected in a well? Let a light down. If it goes out, the gas is there; if it burn dimly when near the bottom, there is enough of the gas to make descent dangerous. A very good plan is for the man who goes down a well to take a candle with him. He must hold the candle considerably below his mouth. If the light goes out or dimly burns he must stop at once, for another step may bring his mouth into the gas so that it would enter into his lungs.

Now when some of this gas is in a well or pit, how can it be made so safe that a man may go down? There are several expedients for this. One is to let down a bucket frequently, turning it each time upside down in the air to let the gas fall out. This will remind you of the experiment represented in Fig. 17.

Fig. 18.

But even this will not take all the gas out. Well, another expedient is to let down a bundle of burning straw or shavings. This causes an ascending current; therefore if the bundle be held to one side of the well, the heated gas will pass up that side, while cool good air will go down the other to take its place. The manner in which this operates can be illustrated by the experiment in

Fig. 18. In a jar of carbonic acid gas there is placed a flask full of hot water, and corked. It rests on a pad, to keep it in its place at the side of the jar. This heats the gas all around it, and there is therefore an upward current on that side of the jar, while there is a downward current of cool good air at the other side. The two currents are indicated by the arrows. That the gas is driven out can be shown by letting a lighted taper down. If it has gone, the taper will burn as brightly as when outside.

Another expedient is to throw lime mixed with water down the sides of the well. Observe how this operates. You remember that chalk is composed of carbonic acid and lime. Now there is carbonic acid in the well, and if you put lime there so that this gas can get at it, they combine and form chalk. This is the object of having a mixture of lime and water dripping down the sides of the well. The gas unites with the lime, and so chalk is formed, and adheres to the stones. You can see that if dry lime were thrown down it would pass quickly through the gas, and lodge in the water where the gas could not get at it.

There is always, as I have before told you, carbonic acid gas in the air, but it is mixed with nitrogen and oxygen. Why is it thus mixed? As it is heavier than these gases, why does it not lie close to the earth with them above it, as water lies under oil when they are in the same vessel? It is because gases so readily mingle. The least motion causes them to do so, and you know that the air is always in motion. Even when it appears to be at rest there is motion, as you may see by motes floating in the sunbeams in a room.

The mingling or *diffusion* (as it is called) of gases is much the same as that of wine and water. In this respect they differ from oil and water. You may shake oil and water, and yet they do not mingle. The water, after the shaking is over, takes its place below the oil. But water and spirits of wine shaken together, mix thoroughly and remain mixed. So with the gases that form air.

If you pour *alcohol* (this is commonly known by the name of *spirits of wine*) very carefully into a vessel partly filled with water, the water, which is heavier than the alcohol, will remain at the bottom. Just so carbonic acid gas, which is heavier than air, will remain very quietly at the bottom of a well. It is because air in the well is still. If the air and carbonic acid gas could be shaken, as alcohol and water can, they would mingle.

See now what would happen if carbonic acid gas did not mingle with other gases in the air. Being heavier than they it would get below them as water gets below air. It would make a sea of gas, covering all the valleys and plains. You can tell what would be the consequence. No animal could live anywhere except on hills and mountains, for there only above the sea of carbonic acid gas could be found oxygen for breathing.

There are places where carbonic gas collects in large quantities. One in Italy is called the Grotto del Cane, or Dog's Grotto. On the floor of this grotto or cave there is always a layer of carbonic gas. The layer is high enough to reach above the head of a dog, but not above the head of a man. A man living near shows the grotto to visitors,

and in doing so he takes a dog in, which of course falls down. He however quickly brings him into the fresh air and with a dash of cold water revives him. The dog falls not merely for want of oxygen, but because the gas does him positive harm.*

Where do you think the gas in this grotto comes from? It comes from crevices in the rocks. It not uncommonly comes from such crevices—also from cracks in the earth, and sometimes bubbles through the water of springs in the neighbourhood of volcanoes. Why, then, does it collect in this grotto? Because it is so shut in, that air does not circulate freely, and therefore gas remains on the floor of the cave.

Persons are sometimes injured by charcoal being burnt in a close room, and even death is occasioned. It is the carbonic gas produced by a union of carbon in the charcoal with oxygen of the air that causes this. Hence you see charcoal never ought to be burned except in the open air, or in a room in which doors and windows are open, or in fireplaces where the chimney supplies a way by which the carbonic gas can escape. You see too what remedy to apply if any one be poisoned by gas from burning charcoal. It is to open doors and windows to let fresh air enter. Remember that doors must be opened as well as windows, for air must come along the floor to drive out the gas.

If a grown person and a child are in a room where charcoal is burned in an open furnace the child will be affected first,

* To realise the difference between this gas and nitrogen, turn to what is said about nitrogen on page 13.

because his mouth is so much nearer the floor than the mouth of the adult.

There is a considerable quantity of carbonic acid gas in bottled beer, porter, champagne, bottled cider, etc. It is this that makes the foam when the cork is drawn. Where is it before we draw the cork? If you hold the bottle up to the light you see nothing but liquid. Gas however is there. It is imprisoned, as we may say, and when the cork is drawn it is set at liberty, and coming to the air it carries up some of the liquid making a froth. In what is commonly called soda-water there is no soda, it is water into which carbonic acid gas has been introduced by a forcing-pump. Sometimes however soda-water is made from two white powders. One is dissolved in water in one tumbler, and the other in water in another. Pouring these waters together there is an effervescence, which I will explain. One of the powders is a carbonate of soda; that is, carbonic acid united with soda. The other powder is tartaric acid, which has a greater affinity for soda than carbonic acid has, just as in obtaining carbonic gas (page 28), hydrochloric acid has a greater affinity than carbonic acid for lime. The tartaric acid therefore takes the soda, and the carbonic gas being set free goes up so quickly through the water as to cause effervescence.

Well, when we drink soda-water, beer, etc., we take some of this gas into the stomach; but poisonous as it is when it goes into our lungs and is there brought into contact with the blood, it not only does no harm in the stomach but is refreshing, and in moderate quantities may do us good.

CHAPTER VII.

THE AIR.

Air. I have already told you much about air, but we will now more particularly consider its composition.

The greatest part of the air is nitrogen, there being about four times as much of that as of oxygen. Of carbonic acid there is a very small *proportion*, as you may realise on looking at the figure, page 22. Although the proportion is small, yet the *quantity* of this gas in the whole of the air is great, for you must remember that the atmosphere is perhaps 45 or 50 miles high. It is calculated that in the atmosphere over every acre of land there are seven tons of carbonic acid gas.

Continual additions are made to the carbonic gas in various ways. Every fire adds to it; for, as you read in Chapters V. and VI., the carbon in the burning of wood, coal, and other substances unites with the oxygen forming carbonic acid gas.

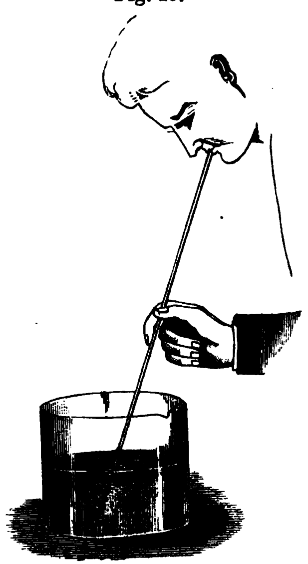
Thus fire lessens the oxygen and at the same time adds to the carbonic acid. If a lighted candle be placed on a plate and covered with a glass jar it will burn brightly at first, because there is enough oxygen in the jar; but soon it will burn dimly, and go out. The reason is that the carbon of the candle unites with the oxygen to form carbonic gas. If, as the candle is about to go out, you lift the jar,

the flame will brighten again, because you let out carbonic acid gas which has fallen to the bottom of the jar, and fresh air comes in to supply oxygen. You remember what you were told about a child and an adult. If you put two candles, one a long one and the other a short one, under the same jar the short one will be first extinguished.

All fires then lessen the oxygen in the air, and add to the carbonic acid gas.

Every animal too, is breathing out carbonic gas. This you can prove by a simple experiment. Put into a glass some lime water. Breathe into this through a tube and, after a little time the lime water becomes milky. The reason is that the carbonic acid gas which came from your lungs united with the lime of the lime water, and formed carbonate of lime, or chalk. After a while the water will become clear, the chalk having settled at the bottom in a fine powder. This will remind you of an instance mentioned before, in which lime and carbonic acid were so introduced that they might unite. I refer to one of the expedients for removing the carbonic acid gas from a well. Try to recollect; but if you cannot, turn to page 35.

Fig. 19.



The quantity of carbonic gas breathed out in twenty-four hours is considerable. It is calculated that a full-grown man breathes out in twenty-four hours more than two pounds of carbonic acid gas, and in this there is not less than half a pound of solid carbon or charcoal. He throws off therefore from his lungs, in the course of a year, nearly 200 pounds of charcoal—considerably more than his weight.

As all animals, from the elephant down to the smallest insect, breathe out carbonic gas, the supply of it to the air from this source must be great.

Animals also take oxygen from the air with every breath. It becomes a part of their blood. You could not live if the blood did not constantly receive oxygen from the air as it passes through the lungs. Death is caused by drowning because oxygen cannot enter the blood. The water prevents it from doing so. You see then how proper it is to speak of oxygen, as I did on page 7, as the lung-food of the body.

Now mark how the air which you breathe out differs from that which you breathe in. That which you breathe out has less oxygen and more carbonic acid gas. The nitrogen is not altered, for as much comes out as goes in.

I will tell you a story of an emigrant ship called the Londonderry. The ship was crowded with emigrants, and many of them were on deck. There came on a storm, and the captain ordered all to go into the cabin. They were here very much crowded, and fresh air came to them only through an opening in the deck. As the waves broke over the vessel sea-water dashed down through this in great

quantities. The captain ordered that tarpaulin (that is a cloth through which neither water nor air can pass) should be nailed over the opening. The people below suffered dreadfully for want of fresh air. The poisonous carbonic acid gas increased every time each person breathed, and no pure air could get to them. They cried out in their distress, but the noise of the storm prevented their being heard. At length one of the emigrants succeeded in forcing a hole through the tarpaulin. He told the captain that the people were dying for want of air. The tarpaulin was taken up at once. Many were dead, and many were dying. The fresh air saved many, just as letting fresh air into the jar revived the expiring flame of the candle.

The viceroy of Bengal, Surajah Dowlah, having taken Calcutta in June, 1756, thrust one hundred and forty-six English people into a loathsome dungeon known as the Black Hole, where in one night, as they could get but very little fresh air, the greater part of them died of suffocation.

All animals then in breathing, and all fires in burning, add to the carbonic acid gas in the air and lessen the oxygen. What is there, then, to hinder the air from becoming more and more loaded with carbonic acid gas, and less and less supplied with oxygen? Here now is a wonderful and beautiful provision of our Creator. He has provided means for constantly taking carbonic acid gas from the air, and of supplying fresh oxygen. Were it not so, all animals would die, and all fires would go out. And what, think you, are the agents that God has appointed to do this work? They are the leaves; the leaves actually breathe, but their

breathing is different from that of lungs. You can see animals that are not small breathe—you can see their chests move; but in the very largest leaves you never see any motion as in breathing. But even a greater difference is in this. While the lungs of animals give out carbonic acid gas, the leaves of plants take it in; and retaining the carbon they give out the oxygen. Every leaf that you see gleaming in the sun is busy pouring out into the air oxygen from all its little pores, or, as we may call them—breathing mouths, and at the same time keeping carbonic acid gas.

I have told you what becomes of the oxygen absorbed by blood in the lungs, page 7; but what becomes of the carbonic acid gas which the leaves absorb? This furnishes carbon for the growth of the plant. You learned in Chapter V. that carbon is a chief ingredient of wood. Now a very large part of this carbon is, under the influence of sunlight, taken in as gas by the pores, or little mouths on the leaves. These are spread like nets and extract the carbon from the carbonic acid gas, and it is carried to all parts of the plant. Whenever you look at a large tree, think how a great part of that solid trunk once moved in the air, and was caught by millions upon millions of little mouths in thousands upon thousands of outspread leaves. Think, too, perhaps some of that hard wood was once in the soft breath coming from your lungs. Even the insect that hums among its leaves may have furnished a little of the carbon which now forms the solid tree.

That which you breathe out may go to leaves far and

near. Suppose it went to the leaves of one tree alone, how much carbon do you think your lungs would give to the tree in a year? More than the weight of your whole body, and that would be enough to make quite a large branch.

You see, then, there is everywhere an exchange going on between leaves and lungs; lungs give carbon to leaves, and keep oxygen themselves. But how is this in winter, when there are no leaves except upon evergreens? Do these leaves take up all the carbon that is then breathed out? No! they are not numerous enough to do this. Does carbonic acid gas then increase in the air, and oxygen lessen? Not at all. It is as in summer when leaves are alive and breathing. I will tell you how this can be. You remember I told you, page 36, that gases readily mix with each other, especially when shaken. Now every motion of air, every gust of wind, shakes the gases that compose the air, and scatters the carbonic acid gas. This gas therefore, we may say, flies on the wings of the wind, and breathed out in one place may thus find its way to many places, not merely miles but thousands of miles distant. That which is breathed out at the north in the winter may thus go to the south to be breathed in by leaves there, and the sunny southern climes send oxygen for the lungs of those who dwell in the north.

The oxygen and carbonic acid gas in the air are continually changing. Oxygen is constantly being used by animals, and by uniting with substances burning. At the same time, fresh oxygen is poured forth from the leaves of all plants into the air; so also the carbonic acid gas is continually

changing, being absorbed by leaves, while new carbonic acid gas is supplied from animals, fires, etc.

These changes seem great and very varied, as well as extensive; it is nevertheless truė and very remarkable, that in the midst of all such changes and chances the air in all parts of the earth has always the same exact proportions of these gases. If a gallon of air from Europe, and another from Asia, and another from Africa were examined by a chemist, he would find that each of them had the same amount of nitrogen, oxygen, and carbonic acid gas that a gallon of English air has. How wonderful this is! In these exchanges which are going on between leaves on the one hand, and lungs, fires, etc., on the other, how is this balance so nicely kept? Men do not know; but the Creator understands it, and He has all power, and secures regularity and suitability, even in so changing a thing as air.

But you may be thinking what I have just said about air is true only of that which is out of doors, free to go "where it listeth." When it is shut up the proportions of its ingredients may be very much changed. Suppose there are many persons crowded into a small closed room; they are using the oxygen and pouring out carbonic gas. Suppose a little fresh air gets in at cracks and loose places about the windows and doors; this is not enough to prevent the air in the room from losing oxygen, and becoming loaded with carbonic gas. After a while the candles burn dimly, and the people complain of headaches, dullness and drowsiness. A gallon of air taken from this room at such a time would be very different from a gallon taken from the air outside.

It would have just as much nitrogen in it, but much less of the life-giving oxygen, and much more of the poisonous carbonic acid gas.

You can easily take air from the room, and examine it by any of the experiments named on pages 32 and 33. Suppose a common glass bottle be filled with water, if the water be emptied in that part of the room from which you wish to take the air, then the air will enter the bottle.

You know what I told you on page 35 about lime-water. If you put a little lime-water into the bottle and shake it, then pour it into a tumbler glass, you would soon see how much white powder settled down. All this comes from the carbonic acid gas in the air of the room.

Think now what happens when the doors of such a room are opened and people go out. The carbonic acid gas becomes diffused far and wide, to be taken in by the mouths or pores of leaves, and fresh air supplies its place.

Great harm is done to the health by breathing air so loaded with carbonic acid gas. It may not be felt at the time; but if such air be often breathed, a little harm done each time will soon produce very serious results.

A few persons were quickly killed on the Londonderry, and in the Black Hole at Calcutta; but many are killed every year by breathing bad air in rooms, and yet they do not know it, because it is done so slowly.

CHAPTER VIII.

HYDROGEN.

Hydrogen. Water is composed of oxygen and hydrogen. Of oxygen you have learned much in a previous chapter. Hydrogen is the lightest of all substances; a metal called platinum is generally called the heaviest (see pages 87 and 99). If a very small shot were a bulk of platinum, a very large cannon ball would show the bulk of an equal weight of hydrogen. If a bullet represents air, then fifteen bullets would represent the bulk of an equal weight of hydrogen. A balloon, therefore, filled with hydrogen goes up very swiftly in the air.

In every nine pounds of water there are eight of oxygen and only one of hydrogen. But as oxygen is sixteen times as heavy as hydrogen, the bulk of the hydrogen in any portion of water is twice as great as that of the oxygen.

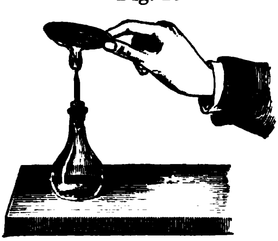
Hydrogen burns with a faint flame, giving little light, but very great heat. How strange that oxygen, by which other things are made to burn, and hydrogen, a gas that does burn, united together form a liquid that puts out fire!

But what will seem stranger still is that when hydrogen is burned in oxygen water is formed. In burning, the oxygen and hydrogen combine. Not an atom of either is lost,

just as none of the carbon and oxygen are lost when carbon is burned in oxygen; the atoms merely go into a new condition, uniting to form a liquid. In doing this, the bulk of both is made much smaller. What we call steam or vapour is first formed; as this cools, dew appears in little drops; these drops mix and then water, as we usually see it, begins to gather.

If hydrogen be burned in air, it combines with the oxygen and forms water. It will have nothing to do with the nitrogen which is in the air but lets that alone, taking the oxygen only. There are many ways in which you can see that water is formed by the burning of hydrogen in air.

Fig. 20.

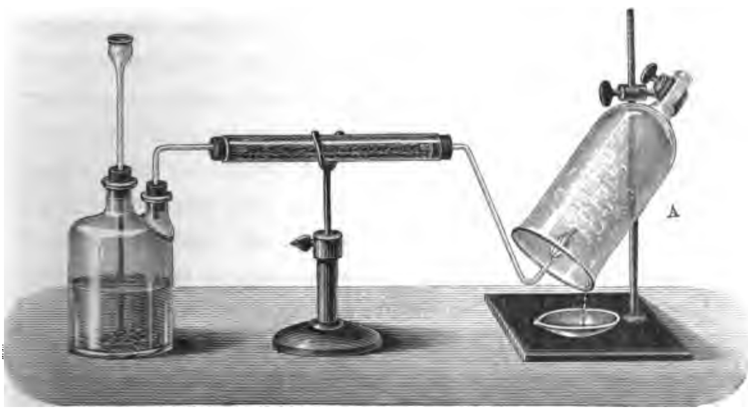


One is represented in Fig. 20. This figure you have seen before, in the first chapter, page 2, and the experiment was then partly explained. You are now prepared to understand a fuller explanation. Carbon and hydrogen are combined in the tallow or gas. Yes; this lightest of all gases helps to form a solid substance. As melted tallow goes up the wick, air brings oxygen to it all around, and heat makes this oxygen unite with both carbon and hydrogen in the tallow or gas. If under a jar placed as the jar or receiver marked H is, in Fig. 22, a lighted candle be placed, then by the oxygen uniting with carbon, carbonic acid gas is formed. This being colourless and transparent, you do not see it. But it is in the jar. Uniting with hydrogen, oxygen forms water. This goes up in vapour with the

carbonic acid gas, and so also you do not see that. But the inside of the glass being cool, this vapour soon collects on it. The glass therefore becomes dim, and after a little time there is enough water to form drops and trickle down into the plate.

In Fig. 21 you have another experiment. Here hydrogen alone is burned without carbon. For making hydrogen, the

Fig. 21.

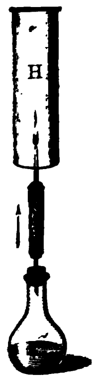


bottle that you see contains materials, of which I will tell you soon. The flame of the hydrogen passes into the receiver or jar A. The vapour then formed by the union of the hydrogen with the oxygen of the air is condensed in drops inside that glass vessel and trickles down on the plate.

If you take a piece of polished metal, as a spoon or knife-blade, and hold it for a few seconds over a candle or

small gas flame, it will be dimmed by the vapour formed as you have been told on p. 2. Where gas-lights are burning inside rooms, water formed in this manner trickles down the window-panes. If H, in Fig. 22, be considered as a room then water caused by the flame will soon form on the glass.

Fig. 22.



You see how readily oxygen combines with hydrogen. And you may remember that, in a previous chapter, I told you that the oxygen and nitrogen in air would not combine however much they were heated and shaken together; nothing but electricity, as in lightning, can make them unite. One reason for this difference may be if oxygen and nitrogen in air easily united very bad effects would be experienced as I told you in Chapter III. But when oxygen combines with hydrogen the result is water, and that we want in abundance. We want it in air and elsewhere, for dry air would be not only uncomfortable, but very injurious to us. It is water in air in the form of unseen vapour, that helps to make the air so soft and pleasant. But if much of nitric acid and other chemical compounds of oxygen and nitrogen were in air every living thing would be destroyed.

I will now tell you how hydrogen is obtained. Into a retort or bottle some bits of zinc, some water, and a little sulphuric acid, commonly called oil of vitriol, are put. Here the oxygen of the water combines with the zinc, forming oxide of zinc, which as soon as formed combines with the

sulphuric acid, the result of the combination being what is called sulphate of zinc, and thus the hydrogen of the water is set free. This rises and passes out of the vessel, carrying the air that is in the vessel along with it; and soon, when all the air is driven out, the gas comes out alone. In Fig. 23 is represented what is called the "philosopher's candle." Zinc, water, and sulphuric acid are in the bottle, in which is fitted a cork having a tube in it. The gas issuing from the tube can be lighted, just as illuminating gas issuing from a gas-burner. There is great caution required in thus making this gas, for a mixture of it with common air explodes like gunpowder. If therefore, you should hold a light to the tube before all the air is driven out there might be an explosion, and the bottle broken into many pieces.

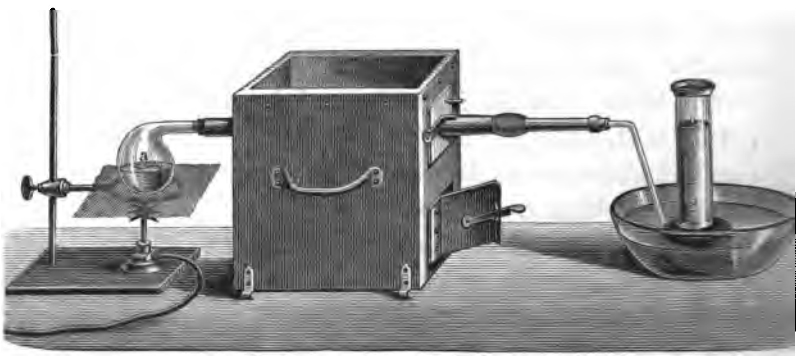
Fig. 23.

Remember it is hydrogen alone that is produced. In bright daylight you may not even see the flame, because it is so faint. A pale blue flame, having small illuminating power, but great heating power, is a characteristic of hydrogen. If you introduce a piece of fine wire it will soon glow, and thus you can know how very much heat is produced by the burning of hydrogen; and you may hence infer that there may be great heat where there is little light (see page 57).

One way in which hydrogen is obtained shows how rapidly oxygen combines with iron. The apparatus is represented

in Fig. 24. You see a furnace with an iron pipe running through it like a gun-barrel. In this pipe are put fine scrapings of iron or bits of needles. At one end of this pipe is another pipe from a flask or retort containing water, and

Fig. 24.

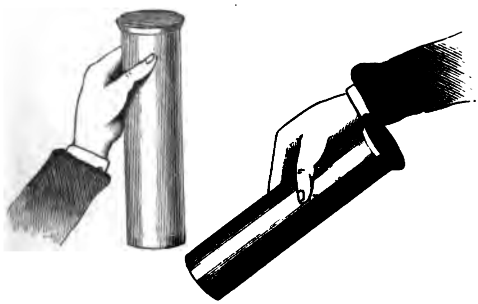


the water is heated by a gas flame or spirit-lamp. As the water boils, steam passes through the iron pipe in the furnace. Now steam is water but very finely divided. As it passes through the red-hot pipe among the scrapings of iron or bits of needles, the oxygen of the water is induced by the heat to combine with the iron, and form an oxide of iron or rust. It parts company therefore with the hydrogen of the water, and so the hydrogen goes out alone through the other end of the pipe. It can be seen passing into the glass jar in the pneumatic cistern.

You remember what was said about pouring carbonic acid gas downward. You cannot do this with hydrogen. It is so light that, the moment it escapes from a vessel, it passes

directly and quickly upward. A jar of carbonic acid gas may stand, and the gas will not go out; but if you set down a jar of hydrogen gas with its mouth upward, the gas will at once pass out, air coming in to take its place. If you pour hydrogen gas from one jar into another, hold

Fig. 25.



them in the manner represented in Fig. 25, the upper jar being the one which is to receive the gas.

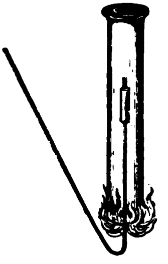
I will make some comparisons between liquids and gases in these respects. If a glass filled with the liquid metal, mercury, is set in a jar, and water poured in, the mercury would remain in the glass, for the same reason that carbonic gas does not rise out of the vessel in which it is when left to stand in the air. As carbonic acid gas is heavier than air, so mercury is heavier than water. But if oil take the place of mercury, then the oil will rise out of the glass and water will enter, as hydrogen gas goes up out of a glass set down in air, air taking its place. As hydrogen then will stay in a jar held in air with its mouth downward, so oil

will stay in a jar immersed in water with its mouth downward.

The manner in which hydrogen burns, differs according to the ways in which the jar is held. If held with the mouth

Fig. 26.

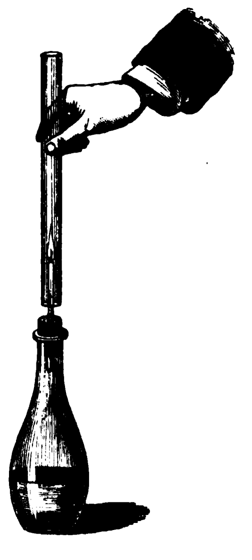
Fig. 27.



upward, the gas, rapidly rising as it burns, bursts with a large flame, as seen in Fig. 26, and under some circumstances attended with a sharp report. But if held with the mouth downward, the gas burns very quietly, issuing slowly from the mouth, as seen in Fig. 27. The gas does not come out freely, because, being lighter than air, it tends upwards and not downwards. As hydrogen is so light, it has a very curious effect upon sounds. If what is called the squeaking toy is made to utter its voice in a jar of hydrogen the sound is very different to the squeak made in the common air. Musical sounds can be made by burning this gas in a glass tube, as represented in Fig. 28. These sounds vary with the size and length of the tube. They vary also as you raise or lower the tube. Great amusement may be

afforded by the variety of sounds which can thus be produced.

Fig. 28.



Hydrogen, when burning, gives a faint light; but the gas that we burn in our houses is very bright, and yet it is partly hydrogen. The reason it gives so bright a light is that carbon or charcoal is united with the hydrogen. On this account it is called by chemists *carburetted* hydrogen. Watch the flame from a gas-burner, and you will see little bright points all the time sparkling upward. These are occasioned by the burning of minute particles of carbon.

The oxygen of the air, as in the case of a candle, unites with both the carbon and hydrogen, forming, with carbon, carbonic acid gas, and with hydrogen, water. And if a glass jar be held over the burner, watery vapour will condense on the inside, as in the case of a candle (see page 3).

When gas escapes without burning, there is a very disagreeable smell; but when burned you do not smell it at all. Why? Because the oxygen of the air unites with it, forming water and carbonic acid gas, and neither of these have any smell. The smell of gas warns us of danger. If it had no smell, we might take a light into some place where there is a great deal of it, an explosion would be the consequence,

and great harm might be done, and perhaps lives lost. Now when there is a leak we smell the gas, and having opened all the doors and windows, we must leave them open for some time before going in with a light, in order that the gas may be so thoroughly mixed with air as to be non-explosive.

CHAPTER IX.

COMBUSTION.

What is usually called *combustion* attends, as you have seen, the combining of oxygen with other substances, as the solid, *carbon*, or the gas, *hydrogen*. Thus, when we have combustion of charcoal, oxygen combines with the charcoal; when hydrogen burns, oxygen combines with the hydrogen; and when iron burns, as you have seen it in a jar of oxygen gas, oxygen unites with the iron.

But we commonly use the term *combustion* only when there are *heat* and *light*, and yet the union of oxygen with other substances often occurs without producing any light. This is when the union takes place slowly. Thus, when iron rusts, oxygen of the air unites with it, but so slowly that no light is given out; there is heat, but so little that it cannot be detected by the sense of touch, because the union is so slow. It is, in fact, a *very* slow fire. Now this same combination takes place when iron or steel burns in oxygen; then we have both *heat* and *light*, because of the union being quickly effected. In both cases it is really combustion. In the one case it is quick, and in the other it is slow. When, then, an iron fence is painted, it is really kept from being burnt. Because the paint keeps the oxygen of the air from the iron.

Now you can understand how water puts out fire. It

shuts out the oxygen of the air from the burning substance. It does the same that paint does to iron. Perhaps you say there is plenty of oxygen in water, as it is composed of oxygen and hydrogen, and throwing water on fire is therefore giving it oxygen. Not at all. Oxygen is not in water *as oxygen;* it has formed a *new* substance with hydrogen, and the hydrogen in this new substance holds the oxygen, so that the fire cannot get a particle of it.

But this is not all. There is another way in which water operates in putting out fire. It takes from the burning substance the heat which is needed to continue the fire. This heat is spent in turning the water into vapour or steam.

When you put out a fire by smothering, you do it in the first of the ways in which I have said that water operates; the oxygen of the air is shut out, and the burning stops merely from want of oxygen. So, if a person's clothes take fire, wrap around at once whatever is at hand—a coat, a rug, or any thing—and thus shut out the oxygen of the air. An extinguisher put over a candle puts out the light by keeping oxygen from it.

Perhaps you may say, people that burn wood cover up fire to keep it; and why does not shutting out of the oxygen of the air put out the fire in this case? Simply because all the air is not shut out; if it were, the fire would not continue. The continuance of the fire depends on letting a very small supply of air through the ashes, so that there may be a *slow* burning.

As combustion results from a union of oxygen with the burning substance, the more freely the oxygen is brought

the brighter will be the fire. When you blow a fire with bellows, you bring the oxygen of the air faster than it would come without the blowing. The coals, perhaps, are just glimmering—kept alive, as we say, that is, *kept on fire*—by the *little* oxygen that is in the still air about them. You blow, and bring more air, and therefore oxygen to them, so they brighten at once. If you could blow *nitrogen*, or *carbonic gas*, they would be put out, for so the oxygen of the air would be kept from them. You will learn more of flames from candles and gas in the next chapter.

A lighted candle is a fire; oxygen keeps it burning; the more oxygen, therefore, that is supplied, the brighter should it burn. Why, then, is it that you blow a candle to put it out? A boy once supposed that he had given a sufficient explanation in saying that the breath knocks the flame over. The true explanation is this. A certain amount of heat is needed to keep up the burning. Now air may be thrown so rapidly against the candle as to carry off so much heat as to stop the combustion; just as the action of a fan carries off heat from your face. In blowing a freshly lighted fire, we have to be careful, or we may blow away too much heat from the coals.

There are contrivances for so carefully adjusting the supply of air or pure oxygen that a flame may give out more heat.

In some of the gas-burners that scientific people use there is a tap to regulate the supply of air, not very unlike the one that regulates the supply of gas.

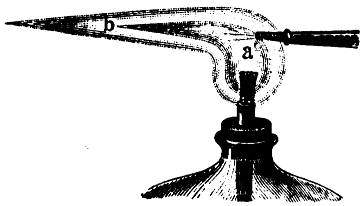
In Fig. 29 you see how air contained in the mouth may be forced along a tube with a very small orifice at the lower end, and directed so as to bend the flame of a lamp or candle as shown in the figure. If you try to do this, remember it must be air and not breath that is directed on the flame. Breath, as you know, is air which has left much of its oxygen in the lungs, and the oxygen of the air is what the flame requires. The tube down which the man is blowing is called a blowpipe.

Fig. 29.

If you examine Fig. 30, you may see why the heat is much increased. The end of the blowpipe enters the hollow part of the flame, and therefore oxygen is supplied where under the ordinary process of combustion none could have access. Hence more of the carbon is burnt than would

otherwise be the case, and between (b) and (c) in the figure there are many atoms of carbon burning, so, as a con-

Fig. 30.



sequence, there is great heat. Very small pieces of metal, such as gold and silver, can be readily melted here.

Fig. 31.

In Fig. 31 you have a picture of one of the contrivances the chemist uses for supplying pure oxygen to a flame. A store of oxygen is contained in the large tin or copper vessel on the left-hand side of the figure. Then by means of a gas tap at (m), and a small jet at (n), the chemist can direct the oxygen upon the flame and turn it as at (c). The heat thus obtained is greater than that from the simple blowpipe as shown at Fig. 29.

There are also contrivances for making lights burn brightly. One of these is a glass chimney. See how it

operates. The heated air and vapour from the light are confined in the chimney, instead of spreading around; they therefore pass very rapidly through the chimney, and so cause a draught. This draws air from below, and of course oxygen comes more quickly to the light. Hold your hand over the chimney, and you will feel a current of heated air and vapour striking it. Be careful not to put your hand too near. This current spreads as soon as it escapes from the chimney, so that, at a distance above the chimney, the hand feels only a small part of the current, and that is cooled.

Another contrivance is to have the wick *flat* instead of round, like a piece of cord. Such a wick presents a larger surface to the air than a round one, and therefore more oxygen can reach it. Some wicks are *circular*, air being admitted to the inside as well as the outside of the circle. A very bright light is obtained in this way. Observe now how we light a fire. We do so by putting something blazing to the combustible substance. Thus we set fire to wood by blazing paper or shavings, and, as we open a gas-burner, we apply a blazing match, and so set fire to the gas. But think a moment *what* causes the match to light. Rubbing, you will say. But how? Friction causes heat enough to combine the oxygen with the phosphorus very rapidly, thus making light as well as heat. You see, then, heat causes what we call fire. Now why is it some substances take fire more readily than others? Why, for example, does a match with phosphorus on its end take fire by friction, while one dipped in sulphur will not? It is because phosphorus has what you may call a greater liking, or, as chemists call it, affinity, for

oxygen than sulphur, and therefore less heat causes them to combine. So charcoal has an affinity for oxygen, but not so great as to cause them to combine by rubbing the charcoal. Phosphorus has a greater affinity for oxygen than any substance I have yet told you about; it therefore takes fire so easily that you must be very careful in handling it. In another chapter I shall tell you about a substance, a metal, which has so great affinity for oxygen that, if you put it on water, it will steal the oxygen from the hydrogen of the water, uniting with it so quickly that it ignites the hydrogen.

Some substances cannot be burned. Gold is one of them. Iron, you have seen, can be burned; that is, it can be made to combine with oxygen; but you may expose gold to a very hot fire, and it will only melt. It will not burn. It has only a very slight affinity for oxygen. And what is true of these two metals in regard to quick combustion is also true of them in regard to that slow combustion I spoke of in the first part of this chapter. Gold *never* rusts in the air; that is, it does not burn* as iron does. Hence, outside work which is gilt, that is, covered with *real* gold leaf (not that leaf called dutch metal, which looks very like gold leaf) never rusts or tarnishes in the air.

* A statement has been published with reference to the fire at Chicago, giving results of the various degrees of damage done to ledgers and business books, &c., which were locked up in iron safes. Some of the papers considered best and strongest suffered most, but all the books with *gilt edges* were, when opened, in a perfect state compared to the others; and the question arises, whether it would not be policy to *gild* the edges of business ledgers, &c., &c., of importance.

CHAPTER X.

GAS-MAKING AND GAS-BURNING.

CANDLES and lamps are gas factories.

Both carbon and hydrogen are in tallow, united as a solid compound; but, as the candle burns, this solid becomes by heat a liquid. See what a cup of melted tallow we have *there*. It is curious to observe how this cup is formed, and kept so, all the time the candle is burning. The heat of the burning wick melts the tallow; that nearest the wick is of course melted first; thus is kept a raised edge all round. If the wick be bent to one side, an edge may be melted, and so tallow flows out of the cup and down the candle.

But liquid tallow at the bottom of the wick must go up the wick and be burned. How is this? It goes up because there is what is called an attraction between the wick and the liquid, and therefore particles of the liquid go among the fibres of the wick. This kind of attraction is commonly called *capillary* attraction, because it was first observed on putting the ends of very small tubes in water. The smaller the tube the higher the liquid was observed to go up in it. Small tubes were called capillary tubes because the duct or bore in them was as fine as a hair, *capilla* being the Latin word for hair.

Liquid tallow coming to the lower part of the flame is changed by heat into a gas, the burning of this gas makes

flame. What is this gas? It is hydrogen gas charged with carbon—very much the same gas with that which comes out of a gas-pipe.

The flame of a candle is a curious thing. It is not really all flame; part of it is gas, which is not burning. If you look carefully at the flame when the air is still, you will see that it is hollow, like a shell. Now the space inside of this shell is filled with gas which is not yet on fire; this looks dark, as you see it through the bright shell of flame.

You can prove that this dark inner part is gas by very pretty experiments. Here is one. Take a small glass tube, and put one end of it in the very middle of the flame—in the dark part. Some of the unburnt gas will pass off through the tube, and you can set it on fire as it issues at the other end. A candle, you perceive, then, is a gas factory; and gas can be taken from it in pipes, as from large gas factories.

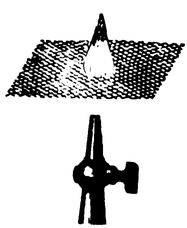
Thrust a match directly into this inner dark part of the flame of a candle quickly, and the end which is in this dark part will not take fire, but only the wood a little way from it, in the burning part of the flame; so, also, if you hold a little splinter of wood directly across the flame, so that it shall run through the dark part, there will be a little in the middle that is not burned, while each side of the splinter will take fire. Or take half a sheet of good glazed note paper and depress it on the flame in the manner shown with gauze in Fig. 32. If now you are expert, you may raise the paper and find a ring singed upon it, but the interior will not be discoloured. Thus it is shown that not only is flame hollow but no great heat is there.

If you take a piece of fine wire gauze, and place it over a candle as in Fig. 32, you will be able to see the inside of the hollow dark space. The flame cannot pass through the gauze for reasons you can hereafter learn.

Fig. 32.

That it does not pass through, you may ascertain for yourself by making the experiment in Fig. 33. Let a stream of gas issue from a gas-burner; hold the piece of wire gauze in the issuing stream, then on applying a lighted taper above it the flame will appear as in the figure. This property of flame not passing through the cool wire gauze has been made of great value by a contrivance of Sir Humphry Davy. You will hereafter learn that in mining for coal, certain dangerous, because explosive, gases are occasionally met with. Now, if the miners used an open, or naked, light a very serious explosion might happen. Sir H. Davy considered that if the flame were carefully enclosed within gauze the accident would be averted; he designed the lamp of which Fig. 34 is a drawing, and Fig. 35 shows the inside arrangements for the oil, wick, etc. Lamps of this kind are now generally used in coal-mines.

Fig. 33.



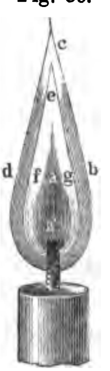
There are really three parts in flame, as represented in

Fig. 34.

Fig. 35.

Fig. 36, the burning shell being composed of two parts. The outer part of the shell (b c d), is not as bright as the inner part (e f g). As the gas (a) rises from the melted and decomposed tallow, some passes into the shell (e f g), where hydrogen burns very briskly, and renders the fine particles of carbon incandescent, or sets them aglow. It is these particles, thus glowing and beginning to burn, that make that part of the flame so bright. As they pass into the outer part of the flame (b c d), their burning is finished by a perfect union with oxygen, forming carbonic acid. In making this union they are not as bright as when the hydrogen first sets them aglow.

Fig. 36.



Similar particles of carbon give brightness to the flame of illuminating gas, as already stated on page 55. We have the same thing in the flame of burning fluid, the fluid being a mixture of alcohol and turpentine. Alcohol burns with a pale flame, as you may see in spirit lamps; it does so because there is not much carbon in it. But add to it turpentine, and then you have a bright light, because there is a larger proportion of carbon in turpentine.

Gas supplied to towns is made generally from coal. You can make gas in a very simple way, with a tobacco-pipe. The bowl of the pipe is filled with pieces of coal about the size of small peas, and closed tight with a layer of clay. The bowl of the pipe is then placed in the fire. In a short time a smoke issues from the stem of the pipe; and if you set fire to it a light will be produced.

Thus gas is made at gas-works. Large iron or clay vessels, called retorts, are inclosed in furnaces. Into these retorts coal is put, and heat drives off the gas. It is impure as it comes off, and must therefore be purified before distributing it in pipes. When it comes, therefore, to us, it is clear, and not like that which comes out of the tobacco-pipe.

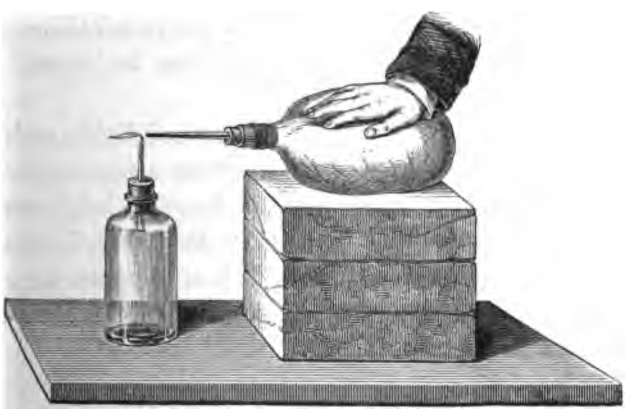
I have spoken of explosions taking place with the gases. Now what is such an explosion? What takes place? If we mix together oxygen and hydrogen, and apply to the mixture a light, there is an explosion. The hydrogen burns *at once* in the oxygen, and, by the burning, water is formed, just as when hydrogen is quietly burned as it comes out of a pipe.

Mixtures of oxygen and hydrogen may be safely exploded in many ways: I will mention one.

Introduce into a strong soda-water bottle, by means of the pneumatic-trough (see page 9), hydrogen enough to occupy two-thirds of the bottle; let in now oxygen enough to fill it; cork the bottle, and take it out of the cistern. *Wrap a thick towel around it*, and, holding it in your hand, draw the cork, and apply a light to the mouth of the bottle. A loud explosion occurs, and water, formed by the union of the gases, bedews the inside. A towel is used so that, if the bottle should happen to break, the broken glass cannot cut the hand.

If a small stream of oxygen and one of hydrogen burn together intense heat is produced. In Fig. 37 you see

Fig. 37.



represented an arrangement for burning these two gases together. Oxygen is in the bag, with the hand pressing upon it to make the gas pass out through the pipe. The end

of the pipe is brought close to the flame of the hydrogen, which comes up from a bottle you see below. Instead of hydrogen the ordinary gas supplied to houses may be used.

The chemist commonly has two bags, or strong metal bottles, containing the gases. From these, two tubes pass, which join in one jet. Such an arrangement is called an oxy-hydrogen blow-pipe.

If you hold a piece of small copper wire in the jet of these two gases, it will burn with a beautiful green flame. If you use iron wire, bright sparks fly merrily. In neither case is oxygen or hydrogen lost; oxygen unites in this intense heat with hydrogen to form water, and with metals to form oxides. Iron rust, or oxide of iron, is formed with the iron, and oxide of copper with the copper. Platinum, the heavy metal mentioned in the beginning of Chapter VIII., cannot be melted in the hottest furnace, but it can be in the flame of oxygen and hydrogen.

You may have heard of the Drummond light, made by causing the oxy-hydrogen flame to strike against a piece of lime. The light produced has the dazzling brightness of the sun, and receives its name from its discoverer, Lieutenant Drummond, of the English navy. It is of great use for many purposes, and can be seen far at sea, and is therefore used very much for signals at night.

CHAPTER XI.

STRIKING FIRE.

PERHAPS you have seen fire struck by nails in the heel of the shoe as they hit a stone. You see the spark, and are satisfied with saying of the phenomenon that, "It is striking fire!" as it is expressed.

But what is the spark? It is something more than a mere show of light; it is a burning substance. What is this substance? It is steel or iron from a nail in the heel, which is knocked off as the heel strikes the stone, and the blow causes heat enough to make the very little bit red hot.

The spark, then, is a particle of burning iron. But how does iron burn? Precisely as steel burned in the jar of oxygen in the experiment noticed on page 12. There is oxygen in the air, and a blow of the heel upon the stone makes the bit of iron so hot as to cause the oxygen of the air to unite with it at once. They unite so quickly as to light up, and so the mite of iron flies off as a bright spark.

The spark falls and goes out. It is so small that you cannot find it. But what is it now? Is it iron? No! for it has been burned. And what is it to burn iron? It is to make oxygen unite with it. The fallen spark, then, is not iron, but iron and oxygen united; that is, oxide of iron.

Suppose that the air were all oxygen, instead of oxygen and nitrogen mixed, striking fire would not end in a little spark; there would be a shower of sparks. And then, too, the nail itself would burn like the steel wire in the jar of oxygen (see page 12). Indeed, the fire, fed by oxygen, might burn the shoe, and your clothes, and your flesh, unless water were applied.

Although the particles of iron are thus cooled, because there is not enough oxygen to keep them glowing, yet there are particles of other substances not so readily extinguished. For example, the lucifer matches, by which we now so commonly obtain a light. A much less severe blow or friction than that of which we have been writing can ignite the ends of these matches, as well as the dry wood of which they are made, and which has been prepared by chemical means for ready ignition.

The invention of matches, by which we can produce a light, has put aside tinder-boxes. About forty or fifty years ago there were no lucifer matches. Persons then obtained a light with an apparatus called a tinder-box. This was a tin box with some tinder in it. The tinder consisted of partially burned rags; there were also a piece of flint and a steel. The person who required the light struck the flint upon the steel, and, as you were told in the beginning of this chapter, the minute pieces of steel ignited as they were struck off. These glowing bits fell upon the tinder and caused in it a smouldering creeping fire. Small matches having the ends tipped with sulphur were applied to these smouldering embers, and by means of

the sulphur ends the matches ignited, and so a light was obtained.

The method which Indians formerly adopted for obtaining fire was more laborious than that of the tinder-box. They sharpened a piece of hard wood to a point, and very rapidly turned this, after the manner of a drill, against a soft piece of wood, having some light chips around. Practice enabled them to move the pointed stick with sufficient rapidity to set fire to the chips. Any one can make two sticks warm by rubbing them together; but to make them hot enough to set any thing on fire is a different matter. The Indian, therefore, must have thought the tinder-box a wonderful invention.

In these cases fire is produced by the oxygen of the air uniting with the wood of the Indian, with the steel of the tinder apparatus, and with the phosphorus of the lucifer match; it is heat in each case that causes the union. The match takes fire easiest, because little heat is required to make phosphorus unite with oxygen. You can produce enough heat for this by slight rubbing. It is supposed by some that many of our fires are occasioned by phosphorus matches carelessly left about. A cat or a mouse might knock them off a shelf; and if they should happen to fall upon something combustible, as paper or clothing, a fire might result.

What you see on the end of a match is not phosphorus alone, but a mixture of this with some other substances, which make it burn more readily than if it were alone. The reason is that they have oxygen in them; and the more oxygen there is to unite with the phosphorus, the more

lively will it burn. In lighting the match, friction makes the phosphorus unite with the oxygen in the mixture, in addition to that in the air.

Machinery is sometimes set on fire from heat occasioned by friction; that is, the iron becomes so hot that it heats the wood sufficiently to make the oxygen of the air unite with it. If the axles of railway carriages are not kept well greased, heat produced by the friction sets the little grease that is in the axle-boxes on fire; that is, makes the oxygen of the air unite with it.

The knife-grinder, with his rapidly revolving wheel or disk of stone, makes sparks fly off, really burning part of the knife that he is grinding. The late Jacob Perkins invented a machine by which steel is burned. A disk of soft iron is made to revolve very fast. If a file be held against the edge of this disk, the friction will cause part of the file which touches the disk to be burnt, and a shower of sparks will be thrown upward. Here you have the same effect as when you strike fire with your heel. It is the union of oxygen with particles of the file that makes the sparks.

CHAPTER XII.

ANIMAL HEAT.

WHAT makes your body warm? You will perhaps say, clothes and fires. No; they help to *keep* you warm, but they do not *make* you so. The heat that makes you warm is produced in your own body, and is made by real combustion. There is, as it were, a fire in your body. It is a real fire, though there is neither flame nor light.

This is one reason why you cannot live without oxygen. This gas is needed to keep up the fire in your body, just as it is needed to keep all fires burning.

In the *results* of the combustion, the burning in your body is like the burning of a common candle. The oxygen of the air unites, as you learned on page 59, with the carbon of the candle to form carbonic acid, and with the hydrogen of the candle to form water. So, also, the oxygen that enters your lungs unites with the carbon of your body to form carbonic acid, and with the hydrogen to form water.

But *where* in the body does the oxygen find the carbon and the hydrogen? It finds them everywhere. They make, in part, your body, as they do the candle. Blood circulates everywhere, to the very ends of your fingers, and so carries the oxygen taken from the air in the lungs. The warmth in your fingers, and in every part of the body, is made by the combination of oxygen with hydrogen and carbon.

But you will ask, "Are carbonic acid gas and water formed in the very ends of my fingers as they are in the burning candle?" Exactly so. "What becomes of them?" you will say. "Do they go from my fingers into the air as they do from the candle?" Perhaps some of the water does. "But the carbonic acid gas, what becomes of that?" It goes in the blood to your lungs, and there is breathed out into the air.

The breathing out of carbonic acid gas I have already told you about in chapter VI. This gas that you breathe out, or *exhale*, comes, then, from all parts of the body. When you breathe into lime-water, and so make chalk, a part of the gas that you make it with came from the very ends of your fingers and toes, and was made there by a sort of fire.

Some of the water, too, that is formed by this fire goes out in your breath; andit goes out in vapour, just as from a burning candle. This vapour can be collected on cold glass as you breathe on it, as the vapour from a candle can be collected by a glass jar or cold spoon held over it.

There is one great difference between your body and the candle. The candle is soon gone, for there is no making up for what is consumed. But your body remains almost the same day after day, although some of it is being constantly destroyed. The reason is that in the body new substance is always being supplied. Your body, then, is more like a lamp fed by a fountain of oil than like a candle.

Part of the food we eat is as fuel; that is, it supplies the carbon and hydrogen that are, as it were, continually burned in our bodies. There are some foods that furnish

much carbon and hydrogen, and so keep up the fire in us. Sugar is one of these; fat is another. Inhabitants of very cold climates, as the Esquimaux, eat large quantities of fat and oil, because they are of use in keeping them warm. They need food that has charcoal in it for fuel, to guard them against the extreme cold of the climate. They love food of this kind. A captain of a vessel invited one of these people to dine with him. His guest declined the coffee and wine which were offered, but, seeing an oil-can near, he took it and drank all the oil. That he liked, for he had been accustomed to drink it to keep himself warm. But coffee and wine he did not think of much account.

Sugar is one kind of food that furnishes fuel for the fire in us. You can hardly believe that a large portion of sugar is charcoal, but so it is. Indeed, sugar and wood are composed of the same things; and as charcoal can be got from wood, so also it can be got from sugar.

I have told you on page 41 that the carbonic acid gas which a man breathes from his lungs in a year contained about 200 pounds of charcoal. Now this carbonic gas came from the fire in his body, and in this fire 200 pounds of charcoal united in his body with oxygen. Where did all the charcoal come from? It was swallowed in the food—in the sugar and fat, etc., that were eaten. You thus swallow every year an amount of charcoal which weighs more than you do, and in burning it keeps you warm.

In running and playing you become heated. Think why this is so. The heart beats quicker than when you are still, and therefore blood flows very rapidly in the arteries and

veins. At the same time, you breathe quickly. Now the quick breathing introduces more air, and therefore more oxygen, into the lungs; more oxygen, of course, enters the blood, and as the circulation is quickened the oxygen is carried everywhere more rapidly. The internal fire must therefore burn more briskly in every part of the body, for the same reason that fire in a fireplace burns more quickly by blowing. Oxygen in both cases, in the fire in the body as well as in that in the fireplace, comes faster to the carbon and hydrogen.

Did you ever think that your body is always giving out heat to the air? Even in very hot weather the air is almost always cooler than the body. You are uncomfortably warm on a hot day, because your body does not give off enough heat.

Many persons, therefore, crowded together, give out much heat. We see this illustrated in large parties. When only a few persons are present the rooms are comfortable; but when many are assembled the air is uncomfortably warm. If a hundred persons are present we may think of them as a hundred fires warming the air.

Again, if you stand without sufficient clothing you become chilled. Observe how this is: air is passing into your lungs, carrying in oxygen, which keeps the fire in you burning; but the fire is not sufficient to keep you warm, because the air is so cold that it can receive much heat from the outside of your body.

How may this be remedied? In two ways. One is to make the fire in your body burn more briskly; this can be

done by exercise, such as running, jumping, working, etc. Then the blood circulates quicker, and you breathe faster, so more oxygen enters, and brightens up the fire, in the same way as the fire in a grate is brightened by air entering it from a pair of bellows. You have seen persons in cold weather strike their arms across the body, and rub their hands together. This is to make the blood flow more freely to the very ends of the fingers, that an abundance of oxygen may be there to unite with the carbon and hydrogen, and so produce sufficient warmth.

Another remedy is to put on more clothing. Thus, the heat which the fire in you is constantly making, is retained. This is the reason why more clothing is needed when you are driving than when you are walking or playing.

For animals that live in cold climates the Creator provides clothing fitted to keep in the heat which is made in their bodies; they are clothed with *furs*. Contrast the polar bear and the elephant in this respect. The bear has a good furry coat, while the elephant, that lives in a warm climate, has only a few straggling hairs upon his skin.

CHAPTER XIII.

IRON-RUST, POTASH, SODA, AND LIME.

I HAVE told you that when iron becomes coated with rust, a sort of burning or combustion causes it. Oxygen unites with iron as it does with charcoal when that is burned. There is no light made, because the combustion is so slow. But when iron rusts quickly, that is, when it is burned in oxygen, there is much light. Perhaps you remember what was said about the burning of iron on page 12 when you saw the same figure as here.

Fig. 38.

Which do you think is heaviest—a piece of iron, or the same after it is covered with rust? The iron, you will perhaps say. Why? Because the rust eats it, says one. And, remarks another, people always say of a stove- or water-pipe, when the rust has made holes in it, that it is rusted away. But let us look at this. When iron rusts, oxygen unites with it. Of course, it will weigh more with this addition. To be sure, oxygen is a very light substance, nearly as light as air. But it has some weight, and this weight is in rust added to the iron. It is to be remembered that a considerable bulk of oxygen is added. It requires much oxygen to make but little rust. Whenever you see rust,

then you can think of a large quantity of this gas being in a very little space when united with the iron; and thus united, it is no longer *gas*, but part of a solid.

In what we commonly call rust, there is something besides oxygen united with iron: there is water. True: it does not show itself as water, for rust is dry. How is this? Water in rust is not a liquid, just as oxygen in it is not a gas. Both the liquid and the gas are now parts of a solid.

You will be surprised when I tell you how much oxygen and water there is in iron-rust. In two pounds of rust there is nearly half a pound of oxygen and about the same weight of water; that is, there is nearly half a pint of water in two pounds of rust, and about 40 gallons of oxygen.

Most metals will, like iron, burn, or, in other words, unite with oxygen; but there are some metals that will not burn at all. This is because they have no liking or affinity for oxygen. Gold is one. If heat enough is applied to melt it, it will not take any of the oxygen of the air to itself. So, also, it may be gilded upon wind-vanes, and exposed to the air year after year, without tarnishing; that is, it will not burn or rust as iron does. Iron exposed in this way rusts in a very little time, unless it be covered with paint to keep the oxygen of the air from it.

There are some metals that like oxygen so well as to unite with it whenever there is an opportunity. Sometimes they burst into flame in doing so. Potassium is one. Sir Humphry Davy, a great English chemist, who was once a poor boy, first obtained this metal.

I will tell you a little about his discovery of it. Every-

body is familiar with potash. Now, for some reasons Davy believed that this is not a *simple* substance, but a *compound* one. He tried some experiments, and at length discovered that it is composed of oxygen and a metal, just as iron-rust is composed of oxygen and iron. He separated the metal from the oxygen, and called it potassium. But the difficulty was to *keep* the metal after it was obtained. It was constantly turning into potash; for there is oxygen everywhere, and potassium and oxygen have a great liking or affinity for each other.

The only way in which this metal can be kept is to shut it in a prison where it cannot get at oxygen. But it is difficult to find such a prison, for oxygen is in almost every substance. It is commonly kept in wood-naphtha, a liquid which happens to have no oxygen in it. The naphtha sold in oil shops and used in lamps is made from coals; there is oxygen in this, and therefore potassium cannot be preserved in such naphtha. With wood-naphtha as a covering to keep out its great friend oxygen, potassium can be preserved pure.

Potassium is a bluish-white metal, quite soft, so that when warm it can be moulded between the fingers almost like wax; but when colder than freezing water it is brittle. It is very light; so light that it floats on water.

If potassium be exposed to the air it rapidly tarnishes, and in a short time is turned to potash, the oxygen of the air uniting with it.

If a little piece of it be thrown upon water, it takes the oxygen from the hydrogen of the water, and bursts into a beautiful violet flame: see Fig. 39. This flame is due to

the burning hydrogen, which is set free by the union of potassium with the oxygen of the water. The hydrogen burns because this union is made quickly, and so heat enough is produced to set fire to it. The colour is given to the flame by the glowing vapour of the potassium. If this metal be thrown upon ice the same burning will occur. The cold cannot prevent the potassium from stealing the oxygen from its companion in the ice —hydrogen—neither will it prevent the hydrogen igniting.

Fig. 39.

It seems strange that a metal should float on water, and burn while floating. When Sir Humphry Davy made the discovery he astonished everybody. Even his brother chemists were astonished. It is related that Davy put a small piece of the newly-discovered metal into the hand of his friend Dr. Wollaston, a celebrated chemist, and Dr. Wollaston spoke of it as being heavy. Davy showed him his mistake by throwing it into water. The philosopher expected to see it sink like lead, and was greatly surprised to see it float and burn.

You have been told in previous chapters that phosphorus has a liking or affinity for oxygen. It likes it so well that we have to keep it imprisoned in water. But you see that potassium likes oxygen much better than phosphorus does, for it will even separate oxygen from the hydrogen in water, although they are very strongly united in that liquid.

Iron-rust is an *oxide* of iron. It is so called because it is

oxygen and iron united. Hence iron, when rusted, is said to be *oxidised.* In like manner, potash is an oxide of potassium.

What is commonly called potash is *really* potash united with carbonic acid, and of this I will tell you in another chapter. What the chemist calls potash, that is, the oxide of potassium, is a powerful substance. It will, like strong acids—the nitric and sulphuric—eat flesh, and so is called a *caustic.*

As potash is an oxide of potassium, so soda is an oxide of a metal called sodium. This metal swims on water like potassium. When thrown upon water it decomposes it, taking oxygen from the hydrogen, as potassium does. A hissing sound is produced, but the escaping hydrogen does not burn unless the water be hot. When it does burn the flame has a beautiful yellow colour, caused by the glowing fumes of the metal.

There is much of this metal in the world, for it is an ingredient of common salt. Like potassium, it is never found alone, but always united with oxygen or some other substance.

Potash and soda are called *alkalies.* They have an acrid taste, very different to that of acids. There is one substance, ammonia, which is called a volatile alkali, because it so readily flies off into the air, *volatile* coming from the Latin word *volo,* I fly. Potash and soda are sometimes termed *fixed* alkalies, in distinction from ammonia, because they have no disposition to fly off, but stay where they are.

Ammonia is a colourless and very pungent gas. It is

composed of nitrogen and hydrogen, and forms with carbonic acid gas the smelling salts with which you are familiar.

Lime was supposed to be a simple substance or element before the discoveries of Sir Humphry Davy. But this, like soda and potash, he found to be an oxide of a metal. This metal, called calcium, is difficult to obtain, because it has so great an affinity for oxygen. It is hard to get calcium out of the company of its friend oxygen long enough to see it. When it is seen it looks like silver. United with oxygen, calcium forms lime, or what is commonly called *quick*-lime. If water be added to lime it is called *slaked* lime. Observe that word *slaked*. People sometimes speak of *slaking* the thirst; so, in the case of lime, there is a thirst, as we may say, for water, and the lime will take a great deal of it. But there is a certain amount that it will take and no more. When it has got that amount its affinity is satisfied, or its thirst is *slaked*. So it is called *slaked* lime.

Lime becomes slaked if exposed to the air, for it has such an affinity for water that it will drink in moisture from the air.

In making mortar the lime is slaked; and so great is the affinity of lime and water for each other, so eager are they to unite, that great commotion and heat are produced, as you have probably often witnessed where mortar is being prepared for buildings.

Slaked lime seems dry, and yet in every four pounds there is one pound of water. This is about the same proportion that

there is in iron-rust. This water does not exist *as* water in the lime. It is no longer a fluid, but part of a solid.

One quarter of the lime in the plastering on walls is, then, water. Pailful upon pailful of water is in the plastering of a single room; and if the house be built of brick, what quantities of water are there in all the plastering and mortar! The common idea of people is, that when plastering and mortar dry, the water that is in them passes into the air, just as it does from a wet cloth when it dries. But only a part thus passes off, a large portion becoming a part of the dry solid wall.

CHAPTER XIV.

METALS AND THEIR OXIDES.

MOST metals unite quite readily with oxygen, but some few do not. I will now describe those metals which are most important and interesting, noticing their oxides at the same time.

Metals are generally considered heavy. One of them, iridium, is the heaviest substance in the world. But some of them, as you have seen, are so light that they swim on water.

Metals are generally solid, but one, mercury, is liquid. You see it in thermometers, which, as you know, are used for showing how hot anything is.

A metal is a simple substance,—an element,—not a compound. There are nearly fifty of these metallic elements, while there are only in the world about a dozen of all other elements. Metals are *opaque;* that is, light cannot pass through them. Glass is *transparent,* and not opaque, for you can see through it; but you cannot see through a piece of iron or tin. Gases are transparent, as you learned in Chapter II. Water is also. You can see substances at the bottom of clear water; but you cannot see anything at the bottom of a cup of mercury.

There are some substances that you cannot *see* through, and yet light can shine through them. They are said to be *translucent.* Metals are neither transparent nor translucent.

When gold is made into very thin leaf by hammering, it is translucent; but, however thin it may be made, it is never transparent.

Metals have a certain brilliancy called *metallic lustre.* Some of them can be polished very highly.

There are certain properties of metals which make them very valuable. There is *malleability.* This word comes from the Latin word for hammer, *malleus.* Gold is very malleable; that is, it can be hammered into very thin leaves. Silver, lead, and tin are also very malleable, though not as much so as gold. Iron is considerably so when heated. Then there is *ductility,* the property by which some metals, as gold, silver, iron, copper, and lead, can be drawn into wire.

Iron is the most valuable and abundant of all metals, and is put to the greatest variety of uses, and the Creator has provided much of it in every part of the world. Here is a piece of rhyme in which some of the uses are mentioned:

"Iron vessels cross the ocean,
Iron engines give them motion;
Iron needles westward veering,
Iron tillers vessels steering;
Iron pipe our gas delivers,
Iron bridges span our rivers;
Iron pens are used for writing,
Iron ink our thoughts inditing;
Iron stoves for cooking victuals,
Iron ovens, pots, and kettles;
Iron horses draw our loads,
Iron rails compose our roads;
Iron anchors hold in sands,
Iron bolts, and rods, and bands;
Iron houses, iron walls,
Iron cannon, iron balls;
Iron axes, knives, and chains,
Iron augurs, saws, and planes;
Iron globules in our blood,
Iron particles in food;
Iron lightning-rods on spires,
Iron telegraphic wires;
Iron hammers, nails, and screws,
Iron in all things we use."

You can think of other uses to which iron is put besides

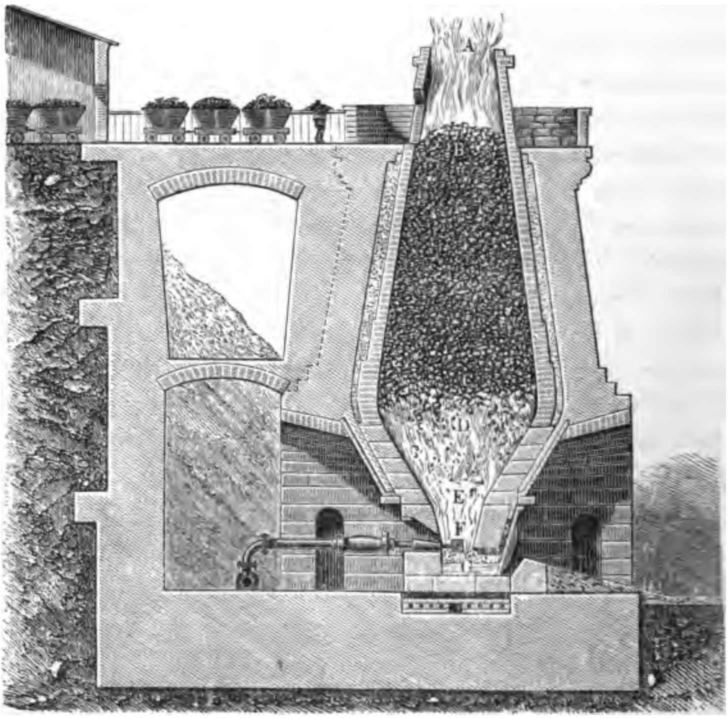
these. I think of a few just at this moment—pokers; shovels; watch-springs; hoops for casks, etc.

Not only is iron put to many uses, but there are very many different methods employed in forming it to these uses. Sometimes it is melted until it becomes liquid, and then it is poured into sand in which has been formed hollows corresponding to the shape of the piece of iron required. Sometimes it is only heated until it is soft, as described on the previous page. Sometimes it undergoes a process you can understand at a future day, and then it is called steel. Even these three kinds of iron differ very much in their properties. Cast iron can bear heavy loads, but cannot be bent, and is not elastic; malleable iron can be bent, and steel is very elastic.

Iron is never found pure, but always combined with oxygen, carbon, sulphur, flint, lime, etc. It is sometimes united with one, sometimes with several of these. When the chemist produces it pure, it is white and soft. The iron we use is obtained from what are termed iron ores. In these ores iron is united with various substances that have been mentioned. It is freed from these by being heated in furnaces.

A drawing of one of these furnaces is shown in Fig. 40. As the ore of iron is brought from the mine it is passed in the small railway waggons you see at the top, and so emptied

Fig. 40.



into the furnace, the flames of which are passing out at A. Coals and other substances are put in with the ore at B. When the iron is in a fluid state it falls down to G, and is drawn out and caused to run into moulds. At F is where

the oxygen of the air is driven in, and so, rapid burning and great heat are produced. From the explanation given on page 61 in reference to the blow-pipe, you will understand why great heat is produced at E. There the iron becomes liquid, and trickles down to G, and the earthy matters mixed with the iron are "vitrified," that is, changed to be like glass or glazed earthenware. At D the iron begins to be separated from the ore. All the iron obtained is more or less impure. Even the very best that can be bought has carbon and flint in it.

There is a great difference between *cast* iron and *wrought* iron. Cast iron is very brittle, wrought iron is not. The difference in composition is this: In every hundred pounds of cast iron there are from three to five pounds of carbon, while there is only from one quarter to half a pound in every hundred pounds of wrought iron. But this is not all; the structure, or putting together, is very different in these two kinds of iron. If you observe the broken edge of cast iron, you will see that the iron is in little grains; the structure, therefore, is said to be *granular*. But wrought iron seems to be composed of threads or fibres of the metal lying alongside each other; so it is said to have a *fibrous* structure.

These two kinds are used for different purposes. Pans and kettles are made of cast iron; but it would not do to have anything made of this which is to be knocked against hard things. If, for example, horse-shoes were made of cast iron, they would be broken by the stones upon which they might strike; they are therefore made of wrought iron.

For the same reason, the nails with which they are fastened to the hoof are made of wrought iron.

Wrought iron can be *welded*,* but cast iron cannot be *welded.* In this welding, which can be done only when the iron is red hot, hammering unites the fibres in the two pieces. You can readily see that this cannot be done where there are grains and not fibres as in cast iron.

Cast iron is so brittle that it cannot be hammered into sheets; it is not then *malleable* in any degree. But wrought iron is so; it is also *ductile,* that is, it can be *drawn out* into wire.

Steel is a kind of iron, or rather a compound of iron and carbon. In every hundred pounds of steel there are from two to two and a half pounds of carbon. In the amount of carbon in it, therefore, it may be said to be half way between cast iron and wrought iron. It may be made from either cast or wrought iron. When made from cast iron it is done by burning out half of the carbon in the cast iron. When made from wrought iron, carbon is added by heating wrought iron with charcoal in boxes.

There are two kinds of steel. One brittle; the other flexible. Some swords can be bent double without breaking, and yet will at once become straight again. The difference between the two kinds of steel is caused thus. If steel be heated, and then *suddenly* cooled, it will be hard and brittle; if it be cooled slowly, it will be soft, and can be hammered like wrought iron. All sharp-cutting instruments are formed

* That is, joined so that two pieces shall be as though they had never been separated.

of steel when it is heated. They are then made as hard as the workman thinks suitable. Some are thus made so brittle as to be easily broken; this you may have learned sometimes by breaking your pocket-knife.

I have spoken of the abundance of iron in the earth. Besides the ores from which it is obtained, there is much in other substances. There are some oxides of iron that abound. For example, almost all black and green stones get their colour from an oxide of iron that is in them. The yellow stains which we sometimes see in marble and other stones result from iron, which, by exposure to air, has become iron-rust; that is, an oxide of iron, as you learned in the previous chapter. There is iron-rust in all soils, in some a great amount, giving to them a yellow or yellowish brown colour.

There is one ore of iron often found in beautiful crystals; and as it has a colour somewhat like gold, it has been supposed to be gold by people that do not understand such matters; it is, therefore, called "fools' gold." People sometimes bring this ore to chemists, expecting to make a fortune. They are very much disappointed to learn that their gold is nothing but a union of sulphur and iron.

CHAPTER XV.

METALS AND THEIR OXIDES—*continued.*

LEAD is the metal next to iron in abundance. Its colour, as you know, is a bluish-gray. It is very malleable. Compared with iron, it is a weak metal. A lead wire would not hold much weight, it is therefore said to have little *tenacity*. This word comes from the Latin word *teneo*, "I hold," and means the power of holding together. It would require a heavy weight to break an iron wire, but a small weight would break a lead one of the same size.

There are three oxides of lead. One of a yellow colour, and is called *litharge*. Another red, used in painting to give a scarlet colour. Then there is another of a dark brown colour. The difference in these oxides is caused by different proportions of oxygen in them.

The most common ore of lead is called *galena*. This is sulphur and lead united, and named by chemists a sulphide or *sulphuret* of lead, as "fools' gold" is a sulphide or *sulphuret* of iron. It is found in crystals of a colour like lead.

There is one way of obtaining the metal from the sulphuret which illustrates chemical affinity. Sulphuret of lead is heated with iron. Now sulphur has a greater affinity for iron than it has for lead, and so leaves the lead and unites with the iron.

The uses of lead are extensive and various. We have it

in the form of sheets and pipes. It is also mixed with other metals. Thus type metal and pewter are composed in part of lead. Bullets and shot are made of lead. Oxides of lead are greatly used; and, besides these, in another part of this book I shall tell you about some valuable substances made by the union of lead with acids.

Extensive lead-mines have been found in all quarters of the globe.

TIN is a bright white metal, very soft and malleable. It does not tarnish easily; that is, it does not readily rust or gather oxygen from the air. Tinware, as you know, easily keeps bright. This tinware is not all tin. There is really more of iron than tin in it. It is sheet iron coated with tin. In making it, thin sheets of iron are dipped into molten tin. Common pins made of brass are whitened by having a thin coating of tin put upon them. This is done by boiling them in a solution of cream of tartar having in it some tin. The cream of tartar is acid and dissolves some of the tin, then the pins take tin from the acid, and so become coated. There are tin-mines in various parts of the world. The most famous are those of Cornwall.

COPPER is a metal of a red colour. It is malleable, and therefore readily made into sheets, in which form it is much used, as, for example, in sheathing vessels. It does not tarnish or oxidize as easily as iron. It conducts heat well, and is used for making various vessels for cooking purposes. Lead would not answer because it melts so easily. Copper is very ductile, and therefore used in the form of wire. It has considerable tenacity, though not so tenacious as iron, for

its wire cannot hold so heavy a weight as iron wire of the same size.

Copper forms a sulphide with sulphur, and this is the most common ore of the metal. This sulphide is often united with the sulphide of iron. Tin and lead are seldom found pure, that is, free from oxygen, sulphur, etc. But copper is sometimes found pure in large quantities. There are four oxides of copper, of different colours. The sulphide is very much like the sulphide of iron—"fools' gold"—but has a deeper yellow colour.

ZINC is a bluish-white metal used chiefly in the form of sheets for covering roofs, lining refrigerators, sinks, etc., and in various other ways. Not long ago it was hardly used at all except for mixing with copper, and so making the compound metal we call—*Brass*. Some one, in experimenting, found that, on heating it to a particular temperature, it could be rolled into sheets. If heated above or below this degree the metal is brittle and cannot be worked. This discovery shows how much good experiments may do. As soon as the discovery was made zinc became extensively used for various purposes.

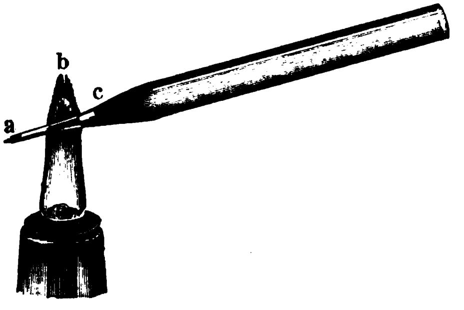
Zinc tarnishes or oxidizes in the air. This you may see in the whitish coating which gathers on it. But observe the difference between that and the rusting of iron. When once coated with this very thin rust, as we may call it, the zinc is protected from any farther action of the air; but iron rusts in and in—there is no stopping it. If zinc did so it would make very poor roofing.

ANTIMONY is a bluish-white metal. It is found like lead

united with sulphur as a sulphide. Its principal use is in mixtures or alloys with other metals. It is often used in the composition of printing type. The medicine called tartar emetic has the metal antimony in it united with an acid.

You may try the following experiment with this metal. Take a glass tube about 3 inches long and $\frac{1}{4}$ inch diameter closed at one end as at (a) in the figure (or like a test-tube). Introduce a little antimony into it, and heat the metal by the flame of a spirit lamp or by gas. It will be vaporized and deposited as a mirror on the cool part (c) of the tube. A similar experiment may be tried with mercury, when a very bright mirror will be produced like a looking-glass.

Fig. 41.



Bismuth is a brittle metal of a reddish-white colour. It also forms part of an alloy.

Aluminum is a bluish-white metal which is always found united with other substances. It is in alum, and hence its name. The chemist obtains it from clay.

Manganese is a grey brittle metal. It is known chiefly from the usefulness of its black oxide which gives a violet colour to glass. The chemist uses this oxide in obtaining oxygen, as it contains a considerable amount of this gas not very strongly united to the metal.

Mercury is a white metal, having a brilliant metallic lustre, and the only one which is commonly liquid. It becomes solid in the extreme cold weather of the Arctic regions. Therefore, when Dr. Kane and others went to those regions they could not use thermometers with mercury in them; they were obliged to have thermometers containing alcohol which does not become solid even in very great cold.

Mercury is sometimes found pure. It is said that the mines in Mexico were first discovered thus: A hunter as he was ascending a mountain caught hold of a shrub to assist him; the shrub gave way at the root, and there ran from the ground a stream of mercury. It was supposed to be liquid silver, and therefore received the name of *quicksilver*.

This metal is commonly obtained from the sulphide of mercury called cinnabar, which varies in colour from bright red to brown-red. It is unlike either mercury or sulphur. The two united make an entirely new substance. Cinnabar when bright red is called vermilion, and is used to give a red colour to sealing-wax.

Silver occurs in nature sometimes pure, sometimes in alloys or mixtures with other metals as lead, copper, etc., and sometimes united with sulphur or some other substance. The most famous mines are in Mexico and South America. This metal is very malleable and ductile. It is not so hard as copper nor so soft as gold.

Gold is not found in nature united with other things as most metals are; but either pure, or mixed with some other metals as an alloy. It is found in rocks, or sands that have been washed down by rivers.

PLATINUM is commonly spoken of (see page 47) as the heaviest of all known substances; but there is another metal iridium found in company with platinum which is a little heavier. Platinum has a colour like steel. It is very ductile and malleable. No common fire can melt this metal; it can be melted however by the heat of the oxy-hydrogen blowpipe, as I told you in Chapter XI.

Mercury, silver, gold, and platinum have been called the noble metals, because when pure and not formed into alloys (see next chapter) they are not tarnished by the oxygen of the air.

CHAPTER XVI.

ALLOYS AND AMALGAMS.

Something has been already said of alloys or mixtures of different metals. Note how these differ from what we call chemical compounds. One difference is this: When two substances form a chemical compound, they unite only in certain proportions; but in an alloy you can mix metals in any proportions. For example, a particular quantity of sulphur will unite with lead to form sulphide of lead. This is a chemical compound; but in an alloy or mixture of lead and tin you may have any proportions of the two metals. It is with alloys very much as with liquids; you can mix tea and milk in any proportions that you wish.

There is another difference. When two substances combine to form a chemical compound the substance formed is not in its qualities between the two that form it; an entirely new substance is formed, and generally very different from either of those of which it is composed. Not so with alloys. Brass is a mixture or alloy of copper and zinc. Its colour is made lighter than copper by the zinc, about one quarter being of this metal. Not only in this, but also in other qualities, the brass is between the two metals.

Take another case. Type-metal is made partly of lead. If it were wholly of lead, types would be soft and very soon worn out. There is therefore mixed with it some other

metal to give the required hardness. Very commonly copper. Sometimes tin is used in place of lead. This makes a better, though more expensive type-metal. Sometimes type-metal is made of zinc, copper, lead, and tin together. In the best type-metal there is some bismuth, which helps to give a clear letter in printing. If you examine printed letters with a magnifying-glass you will see differences according to the types used, and the length of time they have been in use. You will be surprised to find how imperfectly the letters are formed even in the very best print.

Bronze is an alloy of copper with tin, the tin being to the copper as about one to nine. This mixture is much used for statues and small ornamental figures. Bell-metal is a kind of bronze having more tin than ordinary bronze.

Pewter is an alloy of tin with lead or antimony. What is called Britannia-ware is a kind of pewter. When glass and earthenware were not so cheap as now, people very generally used pewter platters and pewter cups.

Brass, I have told you, is an alloy of copper and zinc. There are various other alloys of these metals. You have heard of watches in pinchbeck cases. These are made in imitation of gold watches. The pinchbeck differs from brass only in having more zinc in it. It looks like gold; why, then, is it not as good? Gold, you know, does not tarnish. The oxygen of the air cannot get any hold upon it; but it can get hold of both the zinc and the copper that compose pinchbeck.

There is another alloy of copper and zinc called Tombac, which can be hammered into very thin leaves, making a

spurious or false gold leaf. When finely powdered it is called gold bronze.

You have perhaps heard of German silver. There is no silver in this. It is an alloy of copper, zinc, and another metal called nickel. This latter metal, by its whiteness, gives the alloy a likeness to silver. There is a mixture of silver, nickel, and copper which is a very good substitute for silver, and much used for ornamental purposes. The proportions of these metals in it are silver 30, nickel 25, and copper 55.

There is an alloy which is sometimes made a source of amusement. Teaspoons manufactured from it melt if introduced into hot tea. This alloy is composed of bismuth, lead, and tin; the proportions being, of bismuth 8, lead 5, and tin 3.

The gold and silver in common use are alloys. This is true both of money and of the articles made from these metals.

In the silver coin of England we have an alloy with copper. The object of the copper is to make the coin hard, so that it will not readily wear out. In 100 parts of our silver coinage there are $92\frac{1}{2}$ parts of pure silver and $7\frac{1}{2}$ parts of copper. Silver used for other purposes ought to have just this proportion of copper, in order to preserve a beautiful white lustre. For if there be more copper the article made of the alloy will be tarnished in consequence of the copper being oxidized when exposed to the air.

Gold is softer than silver. To harden it sufficiently, the gold coin of this country is an alloy of 11 parts of

gold and 1 part of copper. The word *carat* is used in expressing the amount of pure gold in any alloy of it. This word means one twenty-fourth. If therefore it is said of any specimen that it is 16 carats fine it is meant that 16 parts out of 24 are pure gold. So if it be said that a specimen is 18 carats fine it is meant that of 24 parts 18 are gold.

Amalgams are mixtures of mercury with other metals. There is one with which you are familiar. It is the silvering on the back of glass in mirrors. This is an amalgam of mercury and tin. Tin foil, that is, tin leaf, is first applied all over the glass; then mercury in which a small quantity of tinfoil has been mixed is poured upon this, and uniting with the tin makes an amalgam, as it is called.

In both alloys and amalgams there is a kind of affinity. There is sometimes a very pretty use made of the affinity which mercury has for gold; it is used to separate the gold from substances with which it happens to be mingled. The material consisting in part of gold is powdered and then shaken with mercury. The gold unites with the mercury forming an amalgam. Even when the material contains little gold, that little may be thus extracted. The gold that is in the dust of jewellers' shops is often recovered in this way.

Thus a solution of gold in mercury is formed. Now how can the gold be got out? The solution is poured upon a closely-woven cloth, which allows most of the mercury to run through. The gold with a little mercury remains in the cloth. Then by the application of heat this mercury is driven off in vapour and gold is left.

Obtaining gold thus is called a process of *amalgamation*.

This word you will often hear applied to other subjects. When people agree or unite readily in their views and plans they are said to amalgamate, so gold and mercury readily unite. You see here an extended use made of a word which was first only applied to one thing. A very good example of a way in which language is built up and enlarged.

CHAPTER XVII.

ACIDS.

I HAVE told you about the union of oxygen with metals forming oxides. Most of the acids are formed by a union of oxygen with certain substances which are not metals, such as sulphur, phosphorus, etc. I will therefore now notice some of these substances and the acids which oxygen forms with them.

Sulphur is a substance with which oxygen and hydrogen unite to form an acid called sulphuric acid or oil of vitriol. We see sulphur ordinarily in two forms, roll brimstone and flowers of sulphur. Flowers of sulphur are obtained by heating sulphur so as to make it rise in vapour, the vapour being condensed, forming fine powder. Roll brimstone is obtained by melting sulphur and letting it run into moulds.

Sulphur is very abundant in nature. It is found as sulphur sometimes in beautiful yellow crystals in the neighbourhood of volcanoes; but it is most abundant in combination with other substances. You have seen that it is united with many of the metals, forming sulphides. The mineral called gypsum or plaster of Paris has sulphur in it, and there is sulphur in vegetables and animals. It is the sulphur in eggs that blackens a silver spoon, forming a sulphide of silver over its surface.

Sulphur and oxygen are mild substances, but, united in certain proportions, they produce an acid of the most corrosive character. Neither sulphur nor oxygen hurt the skin, but the acid composed of them would not only stain, but actually destroy it.

If you burn phosphorus in oxygen, or air which contains oxygen, the phosphorus unites with the oxygen and forms phosphoric acid. This you saw in Chapter III. So, if charcoal burns in oxygen or air, it unites with the oxygen and forms carbonic acid. But if you burn sulphur in oxygen or air it does not form sulphur*ic* acid. The sulphur does not get its full supply of oxygen, as the phosphorus and carbon do. With this partial supply it forms a gas called sulphurous acid gas. It is this that you smell when a sulphur match is burned.

In phosphoric acid the phosphorus has all the oxygen with which it can be made to unite. So, in carbonic acid, the carbon has all the oxygen it can have. But in sulphur*ous* acid gas the sulphur has united with only two-thirds of the oxygen with which it can be made to unite, and with which it must unite to form sulphur*ic* acid.

Sulphur*ic* acid is made by taking oxygen from some substance that has it and giving it to this sulphur*ous* acid gas. I will tell you how this is done. The sulphur*ous* acid gas is made by burning sulphur, oxygen of the air uniting with the sulphur to form it. Then to obtain the other third of oxygen which is needed to turn it into sulphur*ic* acid, this gas is taken into the presence of nitric acid. Nitric acid, as you learned in Chapter IV., has oxygen in it.

From this source sulphur*ous* acid gas gets the needed oxygen, and so becomes sulphur*ic* acid.

Think now what would happen if sulphur on burning in air should unite with enough oxygen to form sulphuric acid. Every time that sulphur is burned corrosive effects of the acid would be seen. If a sulphur match were burned the acid would drop from it and destroy whatever it fell upon. Holes would be continually made in carpets and dresses. You see, then, the wisdom and goodness of the Creator in making sulphur unite with oxygen differently from carbon and phosphorus.

Sulphuric acid has a great liking or affinity for water. If it be left standing in an open vessel it increases by taking moisture from the air. If it stand some months in a damp place it increases so much as to become two or three times as heavy as at first.

If sulphuric acid and water be mixed there is produced a considerable degree of heat. This may be shown by some interesting experiments. I will mention one. Take a vessel of earthenware, or what chemists call a beaker, which is made of thin glass. Do not use a tumbler glass unless it is thin, for the heat is sometimes so great as to cause a thick glass to crack. Pour water in till it is nearly half full, then add about one-third as much sulphuric acid. If now you stir it with a test tube in which is some ether, there will be so much heat produced by the combination of the acid and water as to cause the ether to boil.

I will now tell you about phosphorus, which forms phosphoric acid by uniting with oxygen. This substance is

always found united with other substances. It is commonly obtained from bones. There is between one and two pounds of it in the bones of a full-grown person.

Phosphorus is generally made in the form of sticks. It is white, and has a waxy look. Exposed to air it smokes. This arises from uniting with the oxygen of air. The smoking is really a slow burning, and if it be in a dark place light is produced. Phosphorus takes fire with so little heat that it is necessary to be very cautious in experimenting with it. We should always cut it under water and on taking a piece out we should hold it with a pair of pliers or on the point of a knife.

The smoke that arises from phosphorus when exposed to the air is phosphor*ous* acid. When phosphorus is burned phosphor*ic* acid is formed. Observe the difference between sulphur and phosphorus in this respect. Phosphorus on mere exposure to the air makes phosphor*ous* acid, but sulphur must be actually burned to make sulphur*ous* acid, as noticed on page 106. There is more oxygen in phosphor*ic* acid than in phosphor*ous* acid, just as there is more in sulphur*ic* acid than in sulphur*ous* acid.

I will mention some of the experiments that can be tried with phosphorus.

To prepare for some of these put a piece of phosphorus of the size of a large pea into a phial containing half an ounce (a table-spoonful) of ether. Cork the phial and let it stand for some days giving it a shake occasionally. Pour off the liquid into another phial. This is a solution of phosphorus and is ready for use.

Drop some of this solution upon the hands and rub them briskly together. The ether will fly off in vapour leaving the phosphorus on the hands. If you do this in the evening and make the room dark your hands will be covered with light. The reason is, that the phosphorus unites with the oxygen of air producing combustion. If you rub your hands the light will increase, because the fire is made to burn more briskly. But what is the reason that the hands are not burned in doing this? Because there is so little phosphorus that very little heat is produced.

Moisten a piece of sugar with the solution of phosphorus and drop it into hot water. The heat of the water sends both the ether and phosphorus to the surface. When there the oxygen of the air and the phosphorus combine so rapidly as to ignite the phosphorus, and this sets fire to the ether and off they go in a flame together.

Phosphorus can be made to burn under water. If a stream of oxygen be directed upon a bit of phosphorus under hot water, it will burn brilliantly, the oxygen uniting with the phosphorus causes the burning.

Phosphorus so eagerly unites with oxygen that a little friction produces heat enough to make them unite, and so quickly as to burn. For this reason phosphorus is one of the ingredients on the ends of some matches.

Acetic acid is that which we have in vinegar. It is spirits of wine or alcohol oxidized. Oxygen is added to alcohol to make acetic acid, as it is added to sulphur to make sulphuric acid, or to phosphorus to make phosphoric acid.

Vinegar is made from cider by letting air have access to

the cider. In this case oxygen in air unites with alcohol in cider forming acetic acid. The amount of this acid in vinegar is very small. There are only from two to five gallons in a hundred of the vinegar, the rest is chiefly water.

Tartaric acid exists in many fruits, sometimes as acid, and sometimes united with potash, forming the substance called cream of tartar.

There are various other acids in different fruits, as citric in lemons, oranges, currants, etc.; malic in apples and other fruits, oxalic in sorrel.

There is a remarkable acid I have not yet noticed, commonly called muriatic or hydrochloric acid. It is composed of hydrogen and a very singular gas called chlorine. This gas, which has a pale greenish-yellow colour, is one of the ingredients in common salt, and I shall tell you about it in another chapter. There is one curious thing about hydrogen and chlorine when they are mixed together. If they are mixed in the dark and kept there they do not unite; but bring the mixture to the light, and union takes place, forming the muriatic acid. If sunlight be thrown by reflection from a mirror upon the glass jar containing the mixture, the union is so rapid as to cause a violent explosion. To prevent accidents from broken glass a screen must be put over the jar before light shines upon it.

Chemists call this acid hydrochloric acid. You can readily see a reason for the name; it comes from the two gases which compose the acid. Hydrogen gives the first part, *hydro*, and chlorine the latter part, *chloric*.

What is commonly called muriatic acid is a solution of the gaseous hydrochloric acid in water.

A mixture of this with nitric acid is called *aqua regia,* that is, royal water, because it is the only liquid that dissolves gold—the king of metals. It is very curious that neither of these strong acids alone can affect the gold, but let them make the attack together and gold submits at once. The gold in dissolving is changed into a compound in this way. Nitric acid makes the gas chlorine that is in the muriatic acid with hydrogen part company from the hydrogen. The chlorine thus set free unites with gold, forming a chloride of this metal. We do not get therefore a real solution of gold but a solution of this chloride. Common salt is a chloride of a metal, and I shall tell you about this and other chlorides in another chapter.

Another remarkable acid I will barely notice is commonly called prussic acid. It is composed of carbon, nitrogen and hydrogen. It exists in very minute quantities in bitter almonds, peach blossoms, the kernels of some of the stone fruits, etc., giving to them a peculiar odour and flavour. A flavour is often given to articles of food by the use of bitter almonds, etc., but the quantity of prussic acid thus used is so very minute that it does no harm.

I told you in the first part of this chapter that most of the acids have oxygen in them; prussic and hydrochloric acids have not. They have hydrogen instead, and hence they are called hydrogen acids. There are not many of this class compared with oxygen acids.

CHAPTER XVIII.

SALTS.

I HAVE told you about oxides, which are formed by the union of oxygen with metals. I have also told you about acids, most of which are formed by the union of oxygen with certain substances, as sulphur, phosphorus, carbon, nitrogen, etc. Now these acids unite with metallic oxides to form what are called *salts*.

The term *salt* is applied by chemists to any substance composed of an acid and an oxide. Thus nitric acid united with potash forms the salt called nitrate of potash, or common saltpetre. So sulphuric acid united with potash forms the salt called sulphate of potash. It may seem odd to speak of chalk as a salt, but it is so called by the chemists because it is composed of an acid—carbonic acid, and an oxide—lime, together forming carbonate of lime.

Observe that acids do not unite with metals, but with oxides of metals. Thus, nitric acid does not unite with potassium, but with the oxide of this metal—potash. It is so with all metals and all acids. In forming a salt a compound unites with a compound. The oxide is a compound of oxygen and a metal, and the acid is a compound of oxygen and some substance, as sulphur, so it seems that there must be oxygen on both sides.

Observe the names of the salts. You can always tell by the name which a chemist gives to a salt of what it is composed. Take nitrate of potash. The termination of the first word in the name is *ate*, and signifies that the substance is a salt, the first part of the word shows what acid is in the salt. Potash is the name of the oxide, the other part of the salt. So also the acid in sulphate of potash is sulphuric acid, and that in carbonate of potash is carbonic acid.

But there are some salts the names of which have the termination of the first word in *ite* instead of *ate*. These salts are formed with acids whose names end in *ous*, while the salts which have *ate* in their names are formed with acids whose names end in *ic*. Thus sulph*ite* of soda has sulphur*ous* acid in it, while sulph*ate* of soda has in it sulphur*ic* acid. The salts whose names end in *ate* are more common than those whose names end in *ite*. The former have more oxygen in them than the latter, for the acids that have names ending in *ic* have more oxygen than those whose names end in *ous*.

Some metals have no special names for their oxides, as potassium, sodium, etc., have. In such cases the name of the metal is used in the name of the salts. Thus we say carbonate of iron. It would be more correct to say carbonate of the oxide of iron. If this oxide had a short name as the oxide of potassium has, we should use it.

An acid and an oxide are very different. This is especially true of the alkalies. They have qualities opposite to those of acids. The taste of potash, for instance, is the opposite of sour; and all its other qualities are the opposite of those of

an acid. But when an acid and an alkali unite in certain proportions, the acid destroys all the alkaline qualities of the alkali, and the alkali destroys all the acid properties of the acid.

The white powder known by the common name of cream of tartar is a salt composed of tartaric acid and potash. But this is sour. How is this? Why in this case are the acid properties not destroyed by the alkali? Because there is not enough alkali united with the acid. The salt is not as sour as tartaric acid, for part of the acid quality is destroyed by the potash.

There is another salt made of the same ingredients in which there is enough potash to destroy all the acid properties of the acid. It is called tartrate of potash while the cream of tartar is called the *super*tartrate of potash. Cream of tartar has this name because there is more tartaric acid in it than there is in the tartrate of potash. For the same reason a thing is called superfine when it is more than fine, or superexcellent when it is more than excellent.

Cream of tartar is sometimes called bitartrate of potash. This is because the Latin word *bis* means twice, for this salt has exactly twice as much tartaric acid in it as tartrate of potash has. So there is carbonate of soda and bicarbonate of soda. There is just twice as much carbonic acid in the bicarbonate as in the carbonate.

A salt in which there is just enough alkali to destroy the acid properties of the acid is called a *neutral* salt. You see the reason of this name. A neutral person is one who takes neither side in a dispute. Well! a neutral salt is neither

on the acid nor the alkaline side; so the acid and alkali are said to *neutralize* each other in forming a neutral salt. This word is much used in the common affairs of life, when one effort or influence destroys some other effort or influence, it is said to neutralize it.

CHAPTER XIX.

CARBONATES.

SALTS called carbonates are composed of carbonic acid gas united with oxides of metals. You have already learned a few of them. I shall in this chapter tell you more about these, and notice others that may be interesting and useful.

The oxide of calcium, commonly called lime, united with carbonic acid, forms carbonate of lime. This salt appears under various forms. One is chalk, another is marble. The hard substance marble is composed of the same things as crumbling chalk; we have many examples of a similar character. Sugar in some forms is very soft and crumbling; but sugar-candy is exceedingly hard, and yet nothing but sugar. But we have another example noticed in the chapter on carbon which is much more striking. A diamond, the hardest and most brilliant of all known substances, is one form of carbon, dark and crumbling charcoal is another.

This salt appears in many forms of great beauty. There is an abundance of it; hills and mountains are made of it. When in such large masses it has the name of limestone.

Carbonate of lime does not *readily* dissolve in water. But water will dissolve it especially if there be carbonic acid gas in the water. Water from some springs has this salt, and

it crusts over upon stones and sticks. In caves in limestone regions there are beautiful displays of the formation of limestone from water in which this salt is dissolved. As water drips from the roof, some carbonate of lime remains, forming a projection pointing downward very much like an icicle. At the same time, there is formed underneath on the floor of the cave a little hillock of the limestone from the water that drops there. That formed above is called a *stalactite*, and that below a *stalagmite*.

When there are many of these stalactites and stalagmites, and they have been forming for a long time so as to reach a great size, they make a splendid appearance. Stalactites and stalagmites present every variety of form and arrangement, when the place where they are is lighted with torches, it looks like a scene of enchantment.

I have told you something about quick-lime on page 85. This is the oxide of calcium. It is commonly obtained from carbonate of lime. Limestone or chalk is subjected to great heat in a furnace. This makes the carbonic acid quit the lime: and lime, that is oxide of calcium, is left.

Carbonate of potash differs from carbonate of lime. It likes water and dissolves in it readily. It exists in plants and therefore is obtained from ashes.

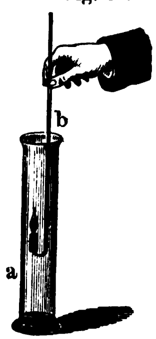
A mixture of carbonate of potash and caustic potash is generally called potash, which is not correct, for this name belongs properly only to caustic potash, that is, the oxide of potassium.

I have told you that if carbonate of lime be strongly heated, carbonic acid is driven off. Carbonate of potash is

very different in this respect. The hottest fire cannot drive carbonic acid from it. If heat could do it we should not have carbonate of potash in ashes, but caustic potash, the carbonic acid being carried off by burning in air.

Here is an experiment you can try with carbonate of potash. Drop a teaspoonful of this salt into a glass vessel containing a little vinegar. There will be brisk effervescence, gas escaping from the liquid. Lower a burning taper fastened to a wire (b) as represented in Fig. 42. The taper will go out. Why? Because the gas which fills the vessel is carbonic acid. Acetic acid in vinegar takes potash from carbonic acid, because of a greater affinity for it. A salt is formed in this experiment by the union of acetic acid and potash. You can tell the name of it by observing what I told you about the names of salts on page 113.

Fig. 42.



If you dissolve potash in water and boil in the solution some dirty greasy rags it becomes dark and dirty, but the rags are white and clean. There is chemistry in this. Potash has an affinity for grease, and in the water we have the two united; but in uniting, the potash has taken out of the cloth the dirt with the grease. This explains the use of soap in washing. In soap there is potash with grease or fat and water, but not so much grease as to prevent the potash uniting with more. Potash alone would be very harsh, but by mixing it with grease we make a smooth article, as soap, that can be easily used.

There is a bicarbonate of potash, a salt which has twice as much carbonic acid in it as the carbonate has. This is sometimes used for raising flour (p. 159). How does it produce this effect? The acid used with it takes potash from the carbonic acid, and this gas, set free everywhere in the dough, causes little spaces or cells. Sour milk is often used as furnishing an acid which will do this.

There are two carbonates of soda, the carbonate and the bicarbonate. That which has most carbonic acid in it, the bicarbonate, is used in making soda powders which you see in boxes. The powder in blue papers is this salt and that in white papers is tartaric acid. If you dissolve one kind of powder in water in one tumbler, and the other kind in another, and pour the liquids together, an effervescence occurs. This is because tartaric acid has a greater affinity for soda than carbonic acid has. It therefore seizes the soda and the carbonic acid gas set free rises through the water and makes a great stir in it.

There is a carbonate of magnesia. This is the common magnesia used in medicine. If heated thoroughly the carbonic acid is driven off, just as it can be driven from carbonate of lime or chalk. This changes the carbonate into an oxide of the metal magnesium. This oxide is the so-called *calcined magnesia.*

Carbonate of lead, called white lead, is used in painting. It is a poisonous salt, and persons have sometimes been made ill by sleeping in rooms recently painted. Some carbonate of lead in the paint escapes, and in breathing enters the lungs.

This salt is often formed in lead pipes used for conveying water: as it dissolves readily, it is carried into the system of those who drink the water, and gradually produces painful disease, and even death. What appears singular is that the more pure the water, the more likely is this salt to form. This is easily explained. There are always oxygen and carbonic acid in water. These act upon lead, unless they are prevented from doing it: the oxygen makes an oxide of lead, and then the carbonic acid unites with this oxide to form the carbonate. Now when water is not pure it commonly has some substances in it which act on lead in such a way as to form a thin coat not soluble in water. This prevents the oxygen and carbonic acid in the water from acting upon the lead. Fortunately the substances dissolved in water are usually such as to make the *fixed* coating, and therefore most waters can be safely carried through lead pipes.

I have alluded to carbonate of ammonia on page 84. This is the common *sal volatile*, so called because it readily diffuses. Fine particles of this salt fly into the nose and tingle it with its pungency. Ammonia is called hartshorn, because at first it was obtained by distilling the horns of deers and harts. It is now usually obtained from bones.

CHAPTER XX.

SULPHATES, NITRATES, AND ACETATES.

The most abundant of the sulphates is sulphate of lime. This is sometimes called gypsum, and sometimes plaster of Paris. It received the latter name because there are immense quantities of it near Paris, and it was first used in that city as a plaster.

Sulphate of lime is very mild and yet it is made of two very active substances. Lime is caustic, and sulphuric acid is very caustic. Mix lime as a gardener sometimes does with weeds and it will destroy them quickly by its caustic power; on page 106 you learnt that if you drop sulphuric acid upon the skin it will destroy it. But let sulphuric acid and lime unite, you have a substance you can handle, and when powdered and wet you can mould it with your fingers. Here we have a striking illustration of the fact that a substance may be wholly unlike the ingredients which compose it. Oxygen the life-supporting gas united with a metal gives lime; and united with sulphur, gives a biting acid.

The forms in which gypsum is found in nature are occasionally very beautiful. Alabaster, which is cut into vases and ornaments, is one of them. Sometimes this salt is arranged in delicate white fibres, and then it is called *satin spar*. It is well named, for it is as elegant as satin. Some-

times it is in very thin leaves laid closely together, and at the same time as clear as water. It is then said to be *foliated*, a word from the Latin for leaf. The common word foliage is from the same source.

Gypsum is used for various purposes: the fact that one-fifth of it is water is of great service. I will tell you how this is. Suppose you wish to make a plaster cast. Subject the powdered gypsum to considerable heat to drive off the water, then make a paste of it. With this paste mould your figure, which should stand till it becomes dry and hard. Observe what happens. Does the plaster merely dry as a wet cloth? that is, does the water which has been mingled with it pass off into the air? Some does; but the rest becomes part of the plaster. The gypsum really makes part of its solid self, as much water as it lost when heated; precisely as quicklime takes water into itself as stated on page 85.

Very pretty copies of coins and medals can be taken with plaster. Buy a little from which the water has been expelled. Moisten some and put it into a small round chip or paper box. Large-sized pill-boxes answer. Press a coin upon the surface. When the plaster is dry and hard, take the coin off, and you will see a good impression in the plaster. To prevent the coin from sticking, oil it very slightly.

The hard-finish put upon room walls is made of plaster. First the wall is covered with common lime mortar. Then powdered gypsum is stirred in water, so as to make a thin paste, and this is nicely spread upon the wall and left to harden.

Sulphuric acid united with soda forms sulphate of soda, or Glauber's salts, as it is called. This salt is in crystals. With magnesia, sulphuric acid forms sulphate of magnesia, which is called Epsom salts. This is in the form of small white crystals. It is really a pretty substance, but has a bitter disagreeable taste, as you may perhaps know. Both of these are called *neutral* salts, for the acid properties of the sulphuric acid are neutralized in them, and the taste detects no trace of them.

There are three sulphates in common language called *vitriols*. They are sulphate of zinc, sulphate of iron, and sulphate of copper. Sulphate of zinc is white, and called *white* vitriol. Sulphate of iron is green, and called *green* vitriol, and sometimes copperas. Sulphate of copper has a fine blue colour, and is called *blue* vitriol.

You can try a very pretty little experiment with sulphate of copper. Dissolve as much as you can in a little water. Hold the blade of your knife in the solution for a few minutes, on taking it out you will find it covered with a red coat which is metallic copper. Think now how this happens. Here is some chemical affinity to be explained. Observe that there is in the water, copper united with sulphuric acid. Now none of that copper can get upon your knife unless it be separated from the acid. How is it separated? The acid liking iron better than copper, quits the copper to take the iron. It unites with the iron and forms sulphate of iron. This salt as it forms is dissolved in the water, and copper clings to the iron giving the red coat.

This experiment explains how metallic copper is sometimes

obtained in mines from a solution of this salt. At one time in Wicklow, Ireland, five hundred tons of iron bars were placed in pits that were full of sulphate of copper in solution. In about a year the bars were all gone. What had become of them? The sulphuric acid in the sulphate of copper had quitted the copper and united with the iron to form sulphate of iron. Copper lay at the bottom of the pits in a sort of reddish mud. This was taken out, and the copper freed from what was mixed with it.

Alum is a sulphate but not a sulphate of *one* oxide, as the sulphates are that have been mentioned. It is a sulphate of *two* oxides; it has two strings to its bow as we may say. It is sulphuric acid united with potash and alumina. With potash you are now well acquainted. Aluminum has been noticed on page 97. Alum is a *double salt*, and there are many such salts. The medicine called tartar emetic is a double salt, it is a tartrate of potash and antimony.

Nitrate of potash formed of nitric acid and potash, is commonly called nitre or saltpetre. It is chiefly interesting as being an ingredient of gunpowder. Gunpowder is made of nitre, charcoal, and sulphur. They are very carefully mixed. When a spark is applied to this mixture the heat is rapidly communicated from grain to grain, and a great quantity of gas is produced all at once. It is this gas striving to get room for itself, that drives the ball out of the gun or cannon.

But how is this gas produced? Nitre is composed of nitric acid and potash. Now there is oxygen in both nitric acid and potash and this oxygen quickly unites with the

carbon or charcoal forming a great amount of carbonic acid gas. In doing so it sets free the nitrogen gas which was in the nitric acid, this acid being composed, as you learned in chapter iii., of oxygen and nitrogen. Carbonic acid gas and nitrogen being the chief gases set free in firing gunpowder produce the explosion.

Think how great the change is in this case. From a small quantity of powder comes out all at once a very large volume of gas. I say comes out, for the gases were locked up in that powder and squeezed, as we may say, into small quarters. See what it is that sets free these condensed gases. It is our lively friend oxygen waked up by fire.

I will notice only one other nitrate, the nitrate of silver. This is a white caustic salt, used in making indelible ink and in photography.

Acetate of lead is commonly called sugar of lead because it has a sweet taste. It seems strange that it should have such a taste when one ingredient acetic acid is so sharp. You can have some idea of its sharpness when you call to mind that it makes but about the twentieth part of the sharpest vinegar.

I will describe a beautiful experiment that you can try with this salt. Dissolve half an ounce of sugar of lead in six ounces (twelve tablespoonfuls) of water in a phial. Fasten in the cork a rod or stick of zinc as seen in Fig. 43. You will soon see a change taking place. The zinc will begin to have little spangles upon it, and these gradually

Fig. 43.

branching out in all directions, form a sort of tree. This tree is made of the metal lead, and is called a lead tree.* The explanation is this. Acetic acid has a stronger affinity for zinc than for lead. It therefore leaves the lead and unites with the zinc forming acetate of zinc. The lead which is separated from the acid forms the tree, while acetate of zinc dissolves in the water, taking the place of the acetate of lead. It takes a day or two for the completion of the tree. If on making the solution it is not perfectly clear add a little good vinegar.

The passage of the acid in this experiment from the lead to the zinc is like the passage of sulphuric acid from copper to iron in the experiment with sulphate of copper given on page 123. In both cases the acid quits one metal to unite with another.

* This tree can be made to have different shapes by a little contrivance. Fasten a small lump of zinc to the under side of the cork by a string through the cork. Then fasten to the zinc fine brass or copper wire, which can be branched out in various directions. Crystals of lead will collect on these branches, and give a more perfect tree shape than the slip of zinc.

I will notice only one other acetate, that of copper, commonly called verdigris. This is a green-coloured salt and very poisonous. It is used in painting. Whenever acetic acid comes in contact with copper, this salt is formed. You can see, therefore, how dangerous it would be to have any cooking operation in which vinegar is used done in a copper vessel unless the copper was protected. This is done by lining copper pans with tin. They are then said to be *tinned*.

CHAPTER XXI.

SHELLS, CORALS, AND BONES.

THE shells on the sea-shore are made of carbonate of lime. All oyster-shells are made of this substance. The lime used for making mortar and other purposes is often obtained from oyster-shells just as we obtain it from limestone. The shells are intensely heated, and the heat, as you have before learned (page 35), drives off the carbonic acid gas and leaves the lime alone.

Whence comes all this carbonate of lime of which shells are made? It is dissolved in the water, as salt is. But how does it get into the water? From the earth and rocks of limestone. It is washed along in brooks and rivers, and at length reaches the sea.

But how, think you, is this carbonate of lime made into shells? Does it gather from the water on the outside of the animals that live in the shells? Does the oyster, for example, lie still and let the shell form by carbonate of lime, settling by little and little from the water, as it crusts upon stones or sticks in a spring? No, this is not the way. All that large rough shell has been swallowed by the oyster and been in his blood. Only a little at a time was swallowed, dissolved in the sea-water; but that little was used in building his shell-house.

Look at an oyster-shell carefully. There are different layers. The outside layer is smaller than the next one, and this is smaller than the next, and so on; and the one next to the oyster is the largest. The outside layer was made when the oyster was very small—a baby oyster as we may say. Then as he grew layer after layer was formed as carbonate of lime oozed from his skin.

All shells are not made *exactly* after the plan of the oyster-shell; but it is true of all, that every particle has been swallowed in the water drank by the animals that lived in the shells.

There is one class of animals which make a singular use of the carbonate of lime they swallow. I mean coral animals. These always stay where they are born, fixed to a strong foundation. That foundation is their skeleton, formed from the carbonate of lime they have swallowed. This skeleton extends into the animal's body. The animal is all the time growing upward adding continually to the top of its skeleton. In the meantime the lower part of its body is dying. It dies below while it grows above.

The effect of all this is that the animal is building a column of carbonate of lime, he all the time sitting on the top of it like a well-fitted cap.

You will be surprised when I tell you that whole islands have been thus built. Long ranges of coast, sometimes hundreds of miles, have been lined with reefs built by these little animals. Some of the tiny builders are no larger than the head of a pin.

I will show you a little how this building was done. Along

the coast of Florida a little way from the mainland there are islands called *keys*. These have been built by the coral animals. They began their work at the deep bottom of the sea, and worked until they reached the surface. Then their work being done, they died.

As coral reefs, they are not fit to live upon, for they are merely carbonate of lime at the surface, and entirely covered at high water. After a while they do become real islands, plants grow, and people live there. I will tell you how this is. Waves, dashing over coral reefs, break off pieces, which are washed toward the middle of the reef; and materials of various kinds washed about in the sea collect there, and sea-weed is thrown upon the heaps in considerable quantities. All this gradually forms a soil, and makes the reef a real island. Seeds are dropped there by birds, or carried in the water, and washed on the land. Grass, flowers, shrubs, and trees soon grow, and then man comes and builds his habitation.

These islands along the coast of Florida will after a while join the mainland; that is, become a part of Florida itself. How is this? The space between the mainland and the islands is continually filling up with mud, which washes in, and after a long time there will be enough to make dry land. Florida has been made in this way. Island after island has been built up by the coral animals, covered with soil, and then joined to the mainland in the way described.

But you may inquire why the coral-builders work away from the mainland, instead of building upon the shore. This is because the work is begun by coral animals that cannot

live in shallow water. They work away till they come near the surface of the water, and then another set of coral-builders fitted to live in shallow water build on the foundations laid by their deep-water friends.

Different kinds of coral animals have different fashions in building. Beautiful specimens of their various work may be seen in mineral cabinets, which, as I have before said, are skeletons of the animals.

Egg-shells are made of carbonate of lime; but hens sometimes lay eggs with no shells on them. Why is this? It is because they have not swallowed enough carbonate of lime. They take it mingled with food in the dust scattered about from broken oyster-shells, chalk, etc. As a canary pecks at the cuttle-fish bone hanging in its cage, some of that dust becomes mingled with its food, and, being swallowed, is used in making shells for the eggs she lays.

Bones of animals are made chiefly of a salt of lime, but not the carbonate; it is the phosphate, a compound of phosphoric acid and lime. The three ingredients in this salt are phosphorus, oxygen, and calcium. Phosphorus is made from bones; that is, it is obtained from bones by separating it from the oxygen and the calcium that are united with it. There is much phosphorus in bones—how much I have told you on page 108.

The phosphate of lime that is in our bones is swallowed in food, and, entering the blood, goes to the bones. Some of this salt is in both animal and vegetable food. It is in the milk upon which infants live.

You see, then, that it is with the phosphate of lime in our

bones as it is with the carbonate of lime in the shells of oysters and other shell-fish,—in the stony skeletons of coral animals, and in the egg-shells of birds the building material is swallowed, and, entering the blood, is carried where it is wanted for building.

Think now whence came all the carbonate and phosphate of lime that are in the bones and shells of animals. They came from the rocks. Yes; the phosphate of lime in your bones was once in the rocks. But how did it get from the rocks into your bones? Rocks are constantly crumbling from the influence of frost, and water, and wind. What crumbles, mixes with earth, gets into plants in the sap, which the roots suck up. If you eat vegetables, or the meat of an animal that has eaten vegetables, you introduce into your stomach, and so into the blood, some of the phosphate of lime from the rocks.

CHAPTER XXII.

GLASS AND EARTHENWARE.

You will think it strange when I tell you that, in treating the subjects named at the head of this chapter, I shall introduce you to a certain class of *salts*. Yet surprising as it is, in glass and earthenware we have salts made with an acid like the other salts of which I have told you.

The acid in these salts is of a very peculiar character. Most acids, you know, are decidedly sour to the taste, and are liquid, as sulphuric, nitric, acetic acid, etc. There is indeed one acid that I have told you much about, carbonic acid, which is a gas, and has rather a pleasant, scarcely acid taste, as you may perceive in drinking soda-water. But the acid we have in glass and earthenware is much more singular than this. It has no taste, and is solid—very solid. It is the substance which you see in flint and quartz, or rock crystal. The shining, clear grains in sand are composed of this acid. It is called silicic acid, or silica. Very hard substances are these grains in the sand, and if you put them into your mouth so far from being sour, they are entirely tasteless.

Why, then, is this silica considered an acid? For several reasons, some of which I will now give.

One is, that, like most of the acids mentioned, it is composed of oxygen united with another substance. Thus, as

sulphuric acid is composed of oxygen and sulphur, and carbonic acid of oxygen and carbon, so silicic acid, or silica, is composed of oxygen and a substance called silicon.

Another reason is, that silica acts like acids in regard to other substances. Thus, as sulphuric acid unites with lime, forming sulphate of lime, and carbonic acid unites with it to form carbonate of lime, so silica, or silicic acid, unites with it to form a substance called silicate of lime.

But perhaps you will ask, why not consider this silica an oxide instead of an acid—an oxide of silicon—as it is composed of silicon and oxygen? First, because nearly all oxides are formed with metals, and silicon does not appear like a metal. Then, again, if silica were an oxide, it should unite with acids to form salts, as the oxides do; but this it has not in any way been made to do. On the other hand, it unites with oxides, as is the case with other acids.

Silica is a very important part of some plants. It is in the stalks of grass, giving them firmness. It is also in the stalks of grain. It is to these and other plants very much what bones are to animals.

But how does this flint or silica get into plants? If you make it very fine indeed, and put it into water, none of it will dissolve. It seems strange, then, that it should go with sap into any plant. To do this, it must be much finer than it can be made by pounding and grinding; and this is done, we know not how, about the roots of plants, so as to cause it to dissolve, and so enter in the sap, probably by means of the potash that is in the ground with the silica. Little is required, and that little is furnished dissolved in

the sap. Then it is lodged just where wanted in the stalk. None of it gets into the kernels of the grains. If so, flour would be gritty, and our teeth soon worn out.

You know that in making mortar we mix sand with the lime. This gives firmness to the mortar. Lime alone and water would not answer. But the sand has this effect; the longer the mortar or plastering remains, the harder it becomes, and, as we see in taking down old houses, is very hard indeed. This is because the silicic acid in the sand gradually and slowly unites with the lime; so that, in the course of years, there is a considerable quantity of silicate of lime, or glass, in plastering. Old plastering is, then, a mixture of glass with mortar, making the whole very firm and hard.

Glass is not one silicate alone, but a compound containing two or more silicates. Thus common window-glass is a silicate of lime and soda. To make it, there are melted together with a very hot fire fine sand, old glass, chalk and soda. Chalk, you know, is carbonate of lime. The heat drives off the carbonic acid, and the lime, released from this acid, unites with the silicic acid of the sand, forming silicate of lime. At the same time the soda unites with this acid, making silicate of soda, and the two silicates uniting form a silicate of lime and soda. This, you see, is a double salt, as alum and tartar emetic are, as noticed on page 124. Common glass is, you know, insoluble; but glass can be made that will dissolve, and it is used as a fire-proof varnish.

Colours are given to glass by various oxides of metals

mingled with the melted glass—oxides of iron, copper, manganese, etc.

It is said that the making of glass was discovered by accident. Some people on a voyage were driven on shore at a very sandy place. There was much sea-weed on the shore dried in the sun. With this they made a fire on the sand, and it was observed that there was mingled with the ashes some substance which had a glassy appearance: it was really glass. You see the explanation of this. The ashes furnished the alkali, and the sand furnished the silica to make the silicate, that is, the glass. If this be true, it is one of many examples we have illustrating the fact that much can be learned by thinking about the common things we see. Be not, then, mere sight-seers as you go through the world, but observers; and observe little things as well as great.

We have clay in earthenware. It is quite pure in porcelain, and very impure in flower-pots and bricks; that is, it is mingled with other things, sand, etc.

Clay, like glass, is a silicate. Perfectly pure clay is a silicate of alumina. But all clay, as we find it, contains silicates of lime, of potash, etc.

The brownish-red colour of bricks and flower-pots is owing to rust of iron in the clay.

Flower-pots and bricks, you know, are porous, and therefore water will soak into them. But generally it is necessary to have earthenware so made that no fluid can pass through its pores. It would not answer to keep preserves in jars of porous earthenware. The watery part would gradually

escape through the pores, and the preserves would become dry.

This can be remedied by *glazing* the surface of the earthenware; that is, a glass surface is given to it, which may be done in various ways. One method you will be interested in, because you can understand the chemistry of it. Fumes of common salt are made to surround articles of earthenware when they are very hot. Now salt is composed of the gas chlorine and the metal sodium. I told you a little about chlorine on page 110, and I shall tell you more particularly about it in the next chapter. You learned something about sodium in Chapter XIII. In the glazing, chlorine leaves the sodium to unite with some of the iron in the earthenware. Then the sodium, thus left by the chlorine, becomes soda by taking some oxygen; and this soda unites with the silica in the earthenware to form a silicate of soda, thus making a soda glass, as we may call it. So, a coating of this glass is over the articles.

Another mode of making earthenware impervious to water is to make the ware partly earthen and partly glass. The ingredients are so selected that you may have the silicates of lime, potash, etc., of which glass is made, thoroughly united with the silicate of alumina or clay. This stops all the pores, and does not merely shut those which are outside, as glazing does.

CHAPTER XXIII.

CHLORINE, BLEACHING, AND COMMON SALT.

THE salts noticed in the previous chapters are made with acids; but there are salts in which there is no acid. These are formed by the union of certain simple substances with a metal. Common salt is one of them. In this substance we have, as stated in the previous chapter, the metal sodium united with a very singular gas called chlorine, and so the chemists call salt chloride of sodium or sodic chloride.

You remember that all compounds of the gas oxygen formed with metals are called oxides, so all compounds of this gas chlorine are called chlorides. Salt is a chloride of sodium, as soda is an oxide of sodium.

Before I tell you about salt I will speak of the gas chlorine. It is of a greenish-yellow colour, and has a powerful and very peculiar odour. Even when diluted with a considerable quantity of air it is very suffocating. If breathed without any air mixed with it death would ensue. Yet to breathe a very little of it, mixed with a great deal of air, does no harm.

Chlorine is of great use in purifying foul air. You perhaps have seen chloride of lime, moistened, set round in dishes where there is sickness of such a kind as to cause bad odours. It is the chlorine that purifies the air. The little chlorine

that escapes does no harm, for it is very largely diluted with air.

The odour of this gas is so peculiar that if you have ever smelled it once you always know it afterwards. You smell it wherever there is bleaching of cloth going on. You smell it, therefore, in paper mills, for the rags out of which the paper is made are bleached by it.

I will tell you about this bleaching. If you put a dry coloured calico rag into a jar of chlorine gas, no effect will be produced on the colours; but moisten the rag before it is put in, and the colours will be extracted by the chlorine.

Fig. 44.

By a method of making chlorine gas, of which you will read presently, let some be made from the contents of a small saucer, as you see in Fig. 44. Place some flowers in a vessel by the side of the chlorine, covering the saucer and flower-pot with a bell-glass, the chlorine will soon bleach the flowers, and make them white.

Chlorine gas dissolves in water. A calico rag dipped in it is very soon made white. It will take out ink-spots also. It has no effect upon printers' ink, however, nor can it bleach woollens.

You see the great usefulness of chlorine in making paper. White paper can be made out of all rags, from which the colours can be removed by chlorine. You see, too, its usefulness in whitening cloth. Formerly cloth was spread

upon grass for sun, rain, and dew to whiten. This, called grass-bleaching, took weeks; but, with the quick bleaching by chlorine, we can do the same thing in a few hours. Some care is required not to have the chlorine water too strong, and to get all the chlorine out of the cloth after the bleaching.

How chlorine bleaches you are not sufficiently advanced in chemistry to understand.

Chlorine can be thus made. Pour into a pint vessel two tablespoonfuls of common sulphuric acid, and add a little more than the same quantity of chloride of lime, or bleaching powder. Add the powder gradually, covering the bottle with a slip of glass each time after dropping some in. Chlorine made in this way will answer for many experiments.

The explanation is this: Sulphuric acid, having a stronger affinity for lime than chlorine has, takes the lime and unites with it. Chlorine, being thus separated, fills the vessel.

Another method is to put some black oxide of manganese into a flask, and pour in enough hydrochloric acid to cover the oxide. In Fig. 45 the flask (a) is made with a bend in the neck, such a flask the chemist calls a "Retort." Gentle heat must be applied, and the gas will pass over into the bottle (b) which is placed to receive it. You observe that the tube passes far into the bottle. This is in order that the chlorine gas may push up the air. Chlorine is two and a half times as heavy as air, and so has no disposition to escape upward. You can tell when the bottle is full by the colour. When full take it from the tube, cork it, and place the tube in another bottle.

The explanation of this formation of chlorine is easy. The oxide of manganese has oxygen in it, while the hydrochloric acid is composed of hydrogen and chlorine, as you learned on page 110. The hydrogen of the acid unites with

Fig. 45.

the oxygen of the oxide of manganese, so the chlorine of the acid is set at liberty.

Although chlorine gas is destructive to life when breathed, yet it supports combustion. If a taper be introduced into a bottle of this gas, it burns with a dull red flame, and a thick cloud of smoke. The explanation is this: Chlorine has a strong affinity for hydrogen, but very little for carbon. It therefore unites with the hydrogen of the taper or candle, and the flame, heating the carbon that is with the hydrogen in the taper, sends it upward in a dense smoke.

So, also, if a slip of paper, moistened with oil of turpentine, be introduced into a bottle of chlorine, the hydrogen of the turpentine will burn, while its carbon will pass off unburnt in a large quantity of very thick black smoke.

See how very widely the ingredients of salt differ from the compound which they make. Chlorine is a gas of most powerful odour, and very suffocating. Sodium is a metal which if put on your tongue would take fire. Yet this gas and metal together form a very mild, pleasant salt, which is everywhere part of the food of man and beast.

Salt is found in all parts of the world. In some parts there are vast deposits of solid salt. The most famous are those of Poland and Hungary and Cheshire. Though salt has been taken from the salt-mines of Cracow for centuries, it is supposed that there is enough to supply the world for centuries more. Some parts of these mines have been shaped into beautiful forms as the salt has been taken out. Chapels, halls, etc., have been made, the roof being supported by huge pillars of salt. When lighted by lamps and torches the appearance is very splendid.

Large lakes of very salt water exist in many parts of the earth.

In England most of our salt is obtained from salt-springs. The most noted of these are in Cheshire. Where the name of a place ends in *wich*, as North*wich*, Droit*wich*, etc., you may know that salt either has been or is now found there. There is between eight and nine times as much salt in the water from these springs as there is in sea-water. To get the water, or brine as it is called, from the springs, wells are dug, and the brine is pumped up by machinery, and conducted to boilers. Here the water is driven off by heat, but sometimes the salt is obtained from the brine by a slower process. The brine is exposed to the sun in extensive

shallow vats, called evaporating pans, and the water gradually passes off into the air, leaving the salt behind. In hot climates, salt is often obtained in this way from sea-water.

I will notice here a salt called chlorate of potash or potassic chlorate. If you remember what I told you about the names of salts, you can tell by the name of this salt what its composition is. The termination *ate*, you know, always indicates the presence of an oxygen acid. The acid in this case is chloric acid, it being chlorine and oxygen united, and this, with the oxide of potassium, makes chlorate of potash. This salt has much oxygen in it; hence it is used in obtaining oxygen. I told you how we obtained oxygen on page 9.

This salt sometimes makes part of the mixture put on the ends of friction matches. It causes the phosphorus to take fire more easily than it otherwise would. Why? Because it gives oxygen to the phosphorus, and thus this substance having at once more oxygen than it can get from the air alone, burns very readily.

CHAPTER XXIV.

CHLORIDES, IODIDES, BROMIDES, AND SEA-WATER.

I HAVE, in the previous chapter, told you about one chloride, the chloride of sodium. But there are other chlorides, for chlorine unites with many of the metals. With some it unites with such eagerness that they burn. Thus, if a fine powder of the metal antimony be sprinkled into a jar of chlorine gas, each particle will take fire. You will therefore have a shower of fire in the jar, and a white smoke issuing from it. This smoke is composed of very small particles of chloride of antimony, for, in burning, the chlorine and antimony unite.

There are two chlorides of mercury, very different from each other. One is calomel, and the other is corrosive sublimate. The difference in their composition is that the corrosive sublimate has exactly twice as much chlorine in it as calomel. Calomel is called the chloride of mercury, while the corrosive sublimate is the bichloride. This difference in the proportion of chlorine makes a great difference in the qualities of the two substances. Corrosive sublimate is very soluble in water, but calomel will not dissolve. Corrosive sublimate is a violent corrosive poison. If swallowed it burns the stomach and the passage to it. But calomel is a white powder like flour, and produces no irritation when taken into the mouth.

While chlorine makes with sodium a mild salt, it forms with zinc a caustic, that is a burning one. Chloride of zinc is very frequently used by surgeons as a caustic.

There are many other chlorides, but it would not at present be interesting to you to hear about them.

There is another substance, similar to chlorine in many respects, in sea-water and in sea-plants. It is called iodine. It exists in sea-water combined with the metals sodium and potassium, as chlorine is combined with sodium. It is also found in many of the productions of the sea, as sea-weed, sponge, etc. In Scotland the preparation of sea-weed, called "kelp," is a large business. Iodine is used in the process of dyeing and in the making of photographic pictures, also in medicine. Iodine is a solid substance, like black-lead, but darker in colour. If heated it turns into a splendid purple vapour or gas, which is one of the heaviest of the gases. If you put a few grains of it in a jar, and place the jar in a sand-bath,* warmed by a spirit lamp, the jar will be filled with beautiful violet vapour. The air in the jar, being very much lighter than iodine vapour, is pushed by it out of the jar. When the jar is full of the vapour, place a piece of glass over it, and take it from the sand bath.

A taper will burn in this vapour, but not as brightly as in the air; but a piece of phosphorus will take fire of itself

* A sand-bath is simply fine sand in a dish. The object is to apply the heat gradually. This can be done, however, with a spirit lamp alone, by keeping it at a little distance from the glass jar. There is an example of a sand-bath in Fig. 45, p. 141.

in it, so eager are the iodine and phosphorus to unite. If some iodine be placed in a jar upon a little stand, with a bit of dry phosphorus upon it, so much heat is caused that they take fire, and a smoke arises. This smoke is partly the violet vapour of the iodine and partly the white fumes of phosphoric acid; for phosphorus, in the burning, unites with the oxygen of the air to form phosphoric acid, and with the iodine to form iodide of phosphorus. While the acid flies off with the iodine that is turned into vapour by heat, iodide of phosphorus remains on the stand.

As chlorine forms chlorides with many of the metals, so iodine forms iodides with them. The iodide of potassium is a very valuable medicine. Iodine forms two iodides with mercury, one of which is of a brilliant scarlet colour. The iodide of silver is made use of in daguerreotyping.

There is another very singular substance in sea-water called bromine. This is a very heavy, reddish-brown liquid, giving out a deep orange-coloured fume. The quantity of bromine in sea-water is very small. It seems to be quite essential, however, for it is always present. It is also in salt springs. Wherever chlorine is, bromine is with it. It must be of some use in sea-water, but what we know not. It never exists in sea-water as bromine, but always in combination with such metals as sodium and magnesium, making bromides. Chemists can separate it from these. This very singular substance is a poison. A single drop put in the bill of a bird destroys life at once.

The three substances of which I have spoken in this and the previous chapter, chlorine, iodine, and bromine, are

peculiar to sea-water. They are always united with other substances, making compounds, chlorides, iodides, and bromides. The source from whence the water of the sea has so much of these and various other mineral substances is, that in the sea are collected washings from all kinds of rocks, sand, and earth. The different salts thus collected and dissolved in the sea are these: chloride of sodium or common salt, chloride of potassium, chloride of calcium, chloride of magnesium, sulphate of lime or gypsum, sulphate of magnesia or Epsom salts, carbonate of lime or chalk, carbonate of magnesia. These are always present in sea-water. There are various other substances which are present in more or less quantities.

We can see of what use in the sea some of these substances are. For example, we can see of what use carbonate of lime is. All those animals that live in shell houses, as I told you in Chapter XXI., need carbonate of lime in the water that they drink, so that it may get into their blood, and be used in making their shells.

Most of the solid matter that is dissolved in sea-water is common salt. Next in quantity are the compounds of magnesium—the chloride of magnesium and the sulphate and carbonate of magnesia. It is these that give the bitter taste, especially the sulphate of magnesia or Epsom salts.

There is a comparatively small amount of these saline matters in rivers, because the water in them is always flowing into lakes and seas; and there is little in lakes, because the water is running out of them as constantly as it runs in.

There are, however, inland seas and lakes that contain more saline matters than the ocean itself. This is partly because they have no outlet, and partly because there is much salt in the neighbourhood. The Caspian Sea, the Dead Sea, and Lake Aral are of this kind.

All saline matters in rivers, lakes, and seas, were once in rocks, and were carried off by the washing of the waters. But, before this was done, they were in various ways broken from the rocks and ground, so as to make a part of the earth under our feet. Here water found them, and carried them into the brooks, rivers, and seas.

But much is returned from the water to the earth again. I will give but one example. Coral animals take carbonate of lime which the earth supplies to the water, and give it back to the earth in reefs, islands, and peninsulas.

The more salt there is in water the more dense it is, and therefore the more it will bear up heavy substances. Thus a man floating in ordinary water has a part of his head above the surface, but in water of the Dead Sea it requires no effort to keep almost to the height of his breast out of the water. A ship there could carry a cargo which would sink it in river water.

There are some pretty experiments which show the difference between salt and fresh water in regard to floating substances. Suppose that you have an egg in a jar half full of water. The egg will be at the bottom of the jar, for it is heavier than water. Pour now some strong brine, which is a mixture of much salt in water, down a long tube to the bottom of the jar. The brine will force up the lighter water,

and with it the egg. Thus the egg will remain at the bottom of the fresh water, floating on the brine.

If you take two jars, putting into one brine, which appears like water, and in the other water only, you will find that the egg floats on the surface of the brine, but sinks to the bottom of the water.

CHAPTER XXV.

SOLUTION AND CRYSTALLIZATION.

THERE is a great difference in the oxides and salts in regard to being dissolved. Some of them will not dissolve, some sparingly, and water takes in large quantities of others. Calomel, for example, which is a chloride of mercury, is perfectly insoluble; that is, not a particle of it can be dissolved in water. But corrosive sublimate, the bichloride of mercury, is very soluble. Magnesia, an oxide of the metal magnesium, is insoluble. But potash, which is an oxide of the metal potassium, is exceedingly soluble. It is very eager for water, and if exposed becomes dissolved in the moisture gathered from the air. It can be dissolved in half of its weight of water; that is, a pound of water dissolves two pounds of potash. Now lime, which is another oxide, likes water, but a thousand pounds of water are required to completely dissolve one pound of lime.

The Creator has made this great difference between potash and lime in regard to solubility, for we may be sure the difference is needed. For example, lime is used in plastering walls, but it would not answer if, like potash, it gathered water from the air and was dissolved. But for the uses to which potash is applied it should dissolve easily. For instance, it is used in making soap, and must be soluble.

Salt dissolves easily, but not as easily as potash. We want to keep salt dry, and this we could not do if it were as fond of water as potash. It sometimes troubles us by gathering moisture from the air, but this is only when the weather is damp; that is, when the air has much water in it.

Let us compare two carbonates in regard to solubility, carbonate of soda and carbonate of lime. Carbonate of soda is very soluble. This is convenient for the uses to which man puts this salt. But carbonate of lime, which appears in the forms of chalk, limestone, marble, etc., is very sparingly soluble. This salt, you know, makes the shells of oysters and other shell-fish. It would not be well to have their shell houses made of a material that water could dissolve easily. And yet, if carbonate of lime were not somewhat soluble, how could it get into the blood of these animals so that it can be made into shell? You see, then, that the Creator has made this exactly right.

But it would be injurious to have so much carbonate of lime in water as there would be if it were very soluble. The rain that falls upon chalk and limestone, which here and there form rocks and hills and even mountains, washes down a little, carrying it down streams into the ocean. That little is enough for building the houses of shelled animals and other purposes. If carbonate of lime were very soluble there would be more than enough. When well-water is what we call "hard," it is generally because there happens to be carbonate of lime in it.

Silica, like carbonate of lime, is sparingly soluble. Sup-

pose it were not soluble at all; all grass and grain would lie flat on the ground, for it is silica that gives them the firmness by which they stand up.

When water has dissolved as much of a substance as it can, we call it a *saturated* solution. This word comes from a Latin word which signifies *to satisfy*. Water is more easily satisfied or saturated with some substances than with others. Potash and lime are in strong contrast in this respect; half a pound of water will not be *satisfied* till it has dissolved a pound of potash, while a thousand pounds of water will be *satisfied* or *saturated* with a pound of lime; that is, it takes two thousand times as much potash to *saturate* water as it does lime.

Observe what it is to have a solid substance *dissolved* in water. Some solid substances can be mixed very thoroughly with water by reducing them to powder, and yet they do not dissolve. Thus calcined magnesia is readily mixed with water, but it is not dissolved. But a substance that dissolves, disappears. You cannot see it. If it have colour, you see that in the water, but not the little grains or particles, as you do in the case of magnesia. A perfect solution is clear and transparent. The substance dissolved is much more finely divided than when only mixed in water; if the solution be left to stand, the solid substance remains, as we may say, hidden among the particles of the water. None of it settles unless some of the water is evaporated; and the more the water evaporates, or flies off into the air, the more will the dissolved substance settle. If the substance dissolved be a coloured substance, it colours the fluid uniformly through-

out, the minute particles of it being diffused everywhere in the fluid.

As water dissolves solids, so air dissolves water. In the clearest day when the air appears to be dry, there is water in it; you do not see it for the same reason that you do not see a solid substance when dissolved in water. Water is dissolved in air; and hot air dissolves more water than cold, just as hot water dissolves more alum than cold water. When water gathers on the outside of cool tumblers in hot weather, it is because the hot air around the tumblers has so much water dissolved in it; and when some of this air is cooled by touching the outside of the tumbler the dissolved water is separated and rests on the tumbler.

As crystals are often formed from solutions, it is proper to speak here of crystallization.

Hot water dissolves twice as much alum as cold water. If you dissolve much alum in hot water, that is, make a saturated solution, when the water becomes cold half of the alum will become solid again; and in doing so it will gather in crystals upon the bottom and sides of the vessel. If you suspend a wire in the vessel of dissolved alum, as it cools the crystals will collect upon this wire. You have perhaps seen baskets made of alum or other crystals. They were made in this way: a basket, made of thin wire, was suspended in a hot solution of alum, and crystals formed upon all parts of the wire.

When the substance used dissolves as freely in cold as in hot water, as is the case with common salt, crystallization is produced only by evaporation; that is, the water passes

away as vapour in the air, and the salt being left reappears in its usual crystalline form.

How beautiful and curious a process crystallization is! In what exact order are the particles arranged to make such very smooth surfaces and such straight edges! They are particles, remember, so small that we cannot see them even with a powerful microscope; and yet, in making a crystal, each one takes its right place. Sometimes this arrangement of particles is quickly done. The most familiar example we have of this is in water, for on taking up a pitcher of water on a very cold morning, part of the water turns all at once into crystals, which shoot across in every direction. If you pour out the water remaining fluid, you can see the crystals. The explanation of the phenomenon is easy—the water in the pitcher during the night became freezing cold, but it was perfectly still, and so the particles of the water remained still; but shaking the pitcher caused the arrangement in a solid crystalline form.

There is the same quick formation of crystals, on a large scale, in every snow-storm. Clouds are reservoirs of water from which snow is made, the water being in the form of fog; and particles of this fog are in a snow-storm continually arranging themselves in crystals, and so fall to the earth.

There are great varieties in crystalline arrangement. I will point out some of them. Mica is arranged in leaves which you can peal off exceedingly thin. This mineral is used for windows in stove doors. The pieces employed for this purpose are really made up of very many of these thin leaves. Crystals of common salt are exactly square

blocks. Crystals of Iceland spar are not square like those of salt, but they are sloping. These are but three of the very many varieties that occur in the shapes of crystals. Sometimes the same substance appears in different forms. This is the case with gypsum, as noticed on page 121. The various forms and arrangements of crystals of water in snow and frost are very beautiful.

In the crystals of some salts there is water, but in others there is none. In carbonate of lime there is no water, but only carbonic acid and lime. In carbonate of soda there is more water than there is of carbonic acid and soda together. In 100 pounds of this salt there are 63 lbs. of water. Yet the crystals are dry crystals; for the water is a part of the solid substance, locked up with the carbonic acid and the soda. By heating you can get this salt without any water in it; but the first thing done on applying the heat is to melt the salt in its own water. As heat is continued this water is evaporated, and the powder of the salt is left behind. It is no longer crystalline; for it cannot be so without its supply of water, which chemists call *water of crystallization*. When this term is used in regard to any substance, we mean the water which is contained by it when in a crystalline form.

Nitrate of potash, or saltpetre, has no water in it. If it had, it might not answer for making gunpowder. Nitrate of soda has no water in it, and it would do for making gunpowder as well as nitrate of potash, were it not for one thing: it gathers moisture from the air. This would not answer for gunpowder, for that must be kept dry. A salt

which thus gathers moisture is said to *deliquesce*—a word which comes from a Latin word meaning to melt. A salt, on the other hand, which on exposure loses its water of crystallization, and changes from a crystal into a powder, is said to *effloresce.* Crystals that do this have a mealy powder gradually forming on their surface. The word effloresce comes from the Latin word meaning to flower. It is as if the mineral flowered.

Many metals show crystals. In the formation of the lead-tree described on page 126, lead becomes crystalline. The tree is made of crystal joined to crystal. If you bend a bar of tin it gives a peculiar sound, which has been called *the cry* of tin. This is supposed to be produced by the rubbing upon each other of the little crystals of which the metal is composed. You can see the crystals of tin beautifully developed by a very simple process. Take a piece of ordinary tin, which is a sheet of iron covered with tin, heat it over a lamp till the coating of tin melts; let it cool quickly, and wash the surface with a little *aqua regia,* the acid mixture mentioned on page 111.

CHAPTER XXVI.

CHEMICAL AFFINITY.

I HAVE told you about chemical affinity on pages 94 and 123, but we will now consider it more particularly.

As you have already learned, when one substance chemically unites with another, it is said to have an affinity for it, or the two substances are said to have an affinity for each other. Sometimes one expression is used, and sometimes the other.

The strength of the liking or affinity is very different in different cases. I will illustrate this. Iron and oxygen have an affinity for each other, but it is not very strong, and therefore works slowly. It takes time for iron exposed to the air to rust. Now look at the metal potassium in contrast with this. As soon as it is exposed to the air oxygen begins to unite with it. It tarnishes at once, and is soon turned into potash; that is, the oxygen of the air has united with the metal. So ready is potassium to unite with oxygen, that if it be thrown upon water it takes the oxygen away from the hydrogen of the water; and so quickly that the hydrogen bursts into flame. Even the coldness of ice will not prevent this, for if potassium be thrown upon ice, it will even then take oxygen out of the ice, and cause the hydrogen to burn.

But iron and oxygen do not always unite slowly. Introduce them to each other in a very hot place, and they will quickly unite. You have seen this in burning iron or steel in oxygen gas. Turn to page 12. When you strike fire with the iron heel of your shoe, the fire does not burn on the heel. The heat produced by the blow only makes a single little particle fly off, and it burns as it flies.

In one of the ways of obtaining hydrogen, as described on page 52, Fig. 24, we see how the affinity of iron for oxygen is increased by heat. As steam, that is, vaporized water passes among pieces of iron, the iron takes oxygen from the hydrogen and lets the hydrogen go on alone. It takes the oxygen very quickly; but observe, it does not set fire to the hydrogen, as the potassium did.

What are called the noble metals—gold, silver, mercury, and platinum—have almost no affinity for oxygen. Not even heat can make them oxidize. You may expose gold to the hottest fire, and oxygen does not unite with it. If mercury be heated it will pass into the air finely divided as vapour, but it does not unite with the oxygen in the air.

I have told you, in Chapter III., how difficult it is to make oxygen and nitrogen unite, and have given there some reasons why it should be so.

Phosphorus and oxygen, however, unite so readily that a little quick rubbing of a match that has phosphorus on the end of it will set it on fire. The phosphorus on the match is not alone, but is mixed with other substances. In this mixture there is very commonly chlorate of potash, a salt

that I told you about on page 143. There is a plenty of oxygen in this, and why it is put with the phosphorus I have already told you, on page 108.

While heat sometimes operates in favour of chemical affinity, it sometimes operates against it, and then it tends to produce decomposition. In carbonate of lime there is carbonic acid and lime united by chemical affinity; but apply great heat to it, as stated on page 117, and the union will be broken. The carbonic acid will pass into the air, leaving the lime alone. Heat in this case overcomes the affinity and decomposes the salt.

But heat does not drive the carbonic acid from carbonate of potash. To do this, you must introduce an acid that has a stronger affinity for potash than carbonic acid has. Acetic acid, as you saw in the experiment noticed on page 118, and tartaric acid will do it.

When we want carbonic acid gas for certain purposes, we use the bicarbonate of potash. This has twice as much carbonic acid as the common carbonate has. People often use it in making bread and cake, introducing some acid to take the potash, that the carbonic acid gas may be set free and raise the dough. Sour milk is sometimes employed to decompose the bicarbonate.

When we separate carbonic acid from carbonate of lime very great heat is required. But we can separate it by using an acid which has a stronger affinity for lime than carbonic acid has. This is illustrated in the mode of obtaining carbonic acid gas, described on page 28. The muriatic acid takes the lime and the carbonic acid goes.

The same can be done with sulphuric acid, for this has a greater affinity for lime than carbonic acid.

Solid substances generally require water to make their affinities operate. If two powders, tartaric acid and bicarbonate of soda, be mixed together dry, there will be no action; but if dissolved, as stated on page 119, as soon as the solutions are mixed the tartaric acid takes the soda, and carbonic acid, thus released from the soda, effervesces. So if you make one heap of the two powders all will be quiet; but pour water on the heap, and there will be a great disturbance as the water introduces tartaric acid to the soda, and carbonic acid has notice to quit. Why the difference? It is because in the dry state the particles do not get near enough. Very fine powders look coarse when examined by the microscope; but the same substances dissolved in water are more minutely divided, and so are nearer to each other.

Heat, then, sometimes favours and sometimes opposes chemical affinity. Indeed, heat and electricity generally accompany chemical combination. Generally, in burning, heat is produced owing to the rapid union of oxygen with the burning substance. Thus, if carbon is burned, the carbon uniting with oxygen causes heat. Heat here comes from the affinity of carbon and oxygen for each other. So, when water and lime are mixed, as in the making of mortar, great heat is produced by the action of the affinity. Sulphuric acid and water have a strong affinity, and, as stated on page 107, when they are mingled considerable heat is caused.

Chemical affinity is definite in its operations. It does not cause substances to unite in all proportions. If two

substances unite to form different compounds, the proportions are so regular that they can be represented by whole numbers. I have already told you about this in regard to some compounds. For example, the bicarbonate of soda has exactly twice as much carbonic acid in it as the carbonate has (page 119), and the bichloride of mercury has twice as much chlorine as the chloride. So, too, in the five compounds of oxygen and nitrogen (page 21), the proportions of oxygen are exactly as 1, 2, 3, 4, and 5.

Observe in regard to the compounds of oxygen and nitrogen, that the nitrogen is of the same amount in all. The difference of proportion is in the oxygen. Of the five compounds there is most oxygen in nitric acid, and least in nitrous oxide or laughing gas. In nitrous oxide the proportion of oxygen is as 8 to 14; that is, in 22 pounds of nitrous oxide there are 8 of oxygen and 14 of nitrogen. But as in nitric acid there is the same amount of nitrogen, but five times as much oxygen, the proportion of oxygen to nitrogen in this acid is as 40 to 14; that is, while there are 8 pounds of oxygen and 14 of nitrogen in 22 of nitrous oxide, there are 40 of oxygen and only 14 of nitrogen in 54 of nitric acid. Can you tell me, then, how much there is of oxygen and of nitrogen in 108 pounds of nitric acid? You can easily answer this question if you apply a very early Rule of Arithmetic, and make a "statement" as is sometimes done in the "Rule of Three," thus:

As 54 : 108 : : 40 : amount of oxygen.
— 54 : 108 : : 14 : amount of nitrogen.

The proportions of the different compounds of oxygen and nitrogen may be stated thus:

		Nitrogen.		Oxygen.
In 22 lbs. of	Nitrous oxide there are	14 lbs.	and	8 lbs.
30 .	Nitric oxide . . .	14	„	16
38 .	Hyponitrous acid .	14	„	24
46 .	Nitrous acid . . .	14	„	32
54 .	Nitric acid . . .	14	„	40

Or you may reason out the result thus:

If in 54 pounds of nitric acid there are	40	pounds of oxygen
Then in 1	$\frac{40}{54}$	„
And in 108	$\frac{108 \cdot 40}{54}$	„
That is in 108	80	„

The difference in the proportion of oxygen is exactly as 1, 2, 3, 4, and 5. There is no variation from this. You cannot make $8\frac{1}{2}$ pounds of oxygen unite with 14 of nitrogen. The 14 pounds of nitrogen will not take a jot more than 8 of oxygen. To make it unite with any more, you must give it twice as much, 16 pounds, and then it will make nitric oxide; or 24 lbs., and then it will make hyponitrous acid, and so on.

Compounds differ from mixtures in these fixed and definite proportions. You can mix alcohol and water in all proportions. The same is true of the mixtures of metals called alloys; but in forming real compounds, substances unite in *exact* proportions.

We see in this exactness of proportions, as we do in crystallization, what order prevails in creation. Nothing is left loose and indefinite, as is too often the case with many of the arrangements of man. Amid all the changes of

matter, whether taking place in quiet, or in the agitation of combustion, or even explosion, there is always in the combinations that occur a strict compliance with the arithmetical proportions that I have indicated. Thus are minute particles and immense worlds arranged alike in perfect order.

CHAPTER XXVII.

WOOD.

So far I have told you about the chemistry of *mineral* substances; that is, substances which neither have life nor are produced by the operations of life. Most people, when the term mineral substances is used, think of solid substances; but air and water are as really minerals as the crystals you see in a cabinet, or the rocks and stones that you see. Wood, sugar, starch, gum, skin, flesh, etc., on the other hand, are not mineral, for some of these have life, and all of them are produced only by the operations of life in either vegetables or animals. It is to this chemistry of life, as we may call it, that we shall attend in the few remaining chapters. I shall begin with the chemistry of vegetables.

Something about the chemistry of vegetables was told in speaking of carbon as entering into leaves and making part of the wood of trees. Now wood is composed of carbon, oxygen and hydrogen—of a solid united with two gases. When we make charcoal, as I described on page 24, we decompose the wood. We send oxygen and hydrogen into the air by heat, and carbon is left.

Though wood can thus be decomposed, you cannot take the ingredients and unite them so as to make wood. If powdered charcoal be mixed with water, there are the in-

gredients of wood together; but you cannot make them unite to form wood. So you have the ingredients of wood, if charcoal be put into a jar filled with oxygen and hydrogen, but they do not turn into wood. If you light the charcoal before putting it into the jar, an effect will be produced, but no wood made; an explosion takes place, the oxygen and hydrogen unite, forming water, and some of the oxygen uniting with the charcoal forms carbonic acid gas. So if you take carbonic acid gas, and mingle it with hydrogen, you have the three ingredients of wood, carbon, oxygen, and hydrogen, but they do not make wood.

See how different this is from what we can do with some of the minerals. For example, take sulphate of copper or blue vitriol: this is composed of three things, sulphur, oxygen, and copper. Now we can make sulphur and oxygen unite to form sulphuric acid, and this acid will unite with the copper, forming sulphate of copper.

Although *we* cannot make the ingredients of wood unite to form wood, it is done in the tree. Let us see how. Much of the carbon is furnished from the air, being taken in by the leaves, as you learned in Chapter VII. Then the water coming in the sap from the roots furnishes oxygen and hydrogen; for water, you know, is composed of these two gases. We may say then that the tree makes its own wood out of charcoal and water.

Wood in every tree is composed of carbon, oxygen, and hydrogen, and there is more difference in the ways in which wood is put together in different trees than you would suppose from looking at the outside, or from seeing the

wood itself with the naked eye. The microscope shows very great differences. In order to see them, exceedingly thin shavings of various kinds of wood, are cut with a very sharp instrument across the grain of the wood. On examining these with the microscope, they are so much magnified that we can see how each kind of wood is put together. In some, as the pine, there is a very open network, with here and there large round openings, while in other more solid woods the spaces are much less. These spaces have great variety of arrangement, and in some cases the arrangement is exceedingly beautiful.

Bearing in mind that in all these varieties there is really the same composition, is there anything you can remember of what I have told you that is somewhat like this? Can you recollect any mineral substance which appears in various forms, and yet in composition is the same in all forms, as wood in its forms? I will mention one, gypsum, noticed on page 121, and perhaps you can remember some others.

But there is still greater variety in wood than I have yet told you. The bark of trees is wood, only in a different form from that which it covers. Hold a leaf so that light can shine through it. That delicate framework you see is a wooden framework. More than this, the skin of the leaf and its filling up are wood. The whole is wood except the sap, and that which gives it its beautiful colour; and what I have said of leaves is true also of flowers. The most delicate flower you can find is made of wood—very, very fine and delicate is such wood, and yet it is wood.

You see a hyacinth growing in a glass vessel in which is

nothing but water. The plant is little else than wood filled in all its cells with water. See how this wood is formed, water furnishes oxygen and hydrogen, and carbon comes from the air.

Every stalk of grain and grass is chiefly wood. In both cases fine particles of flint are scattered in the wood to make it firm enough to stand even in a gale of wind.

Much of the clothing you wear is nothing but wood. You can hardly believe this; but so it is. A shirt, whether made of cotton or linen, is a wooden shirt. Cotton or linen fibre is woody fibre. It is composed of carbon, oxygen, and hydrogen in exactly the same proportions with what we call wood.

You remember I told you in a previous chapter about the old-fashioned tinder-box, charred or scorched linen was always kept in the box to catch the spark from the steel. This is really charcoal, made from linen, just as we make charcoal from wood—that is, by a partial burning. It was used instead of common charcoal because being so fine sparks readily set fire to it.

All paper is wood. When fine as writing paper it is made of cotton and linen rags, and these are wood. If you tear a piece of letter-paper, and look at the torn edge through a magnifying glass or a microscope, you will see very plainly the woody fibres pointing in all directions from the edge.

All the framework, as we may call it, of fruits is wood. All the partitions in fruits are wooden partitions. The orange, you know, is divided into several parts by partitions. These are of wood. The juice of an orange is inclosed in

thousands of little bottles, and these are wooden bottles. Observe and see how pretty they are, and how nicely they are packed in each part of the orange. Their large rounded ends are toward the peel, and their slender pointed ends are toward the middle of the orange. When you eat an orange you crush a multitude of these wooden bottles, and the juice runs out of them, so, when you eat any juicy fruit, you break up wooden apartments or cells that hold the fluid. Even in the most juicy fruits there is wood, and the skins or coverings of fruits are made of wood.

The coverings of seeds are wooden. In nuts the woody substance forming the covering is very dense and hard, as in a cocoanut, walnut, &c. The substance called vegetable ivory is wood.

The very delicate forms in which woody substances sometimes appear remind us of the fine crystals in which minerals sometimes show themselves. Thus saltpetre is sometimes seen on the walls of caverns in fine, needle-like crystals; and, to take another example of a more familiar character, the delicate tracing of frost on our windows is but another form or arrangement of the same material that we have in thick ice.

CHAPTER XXVIII.

STARCH AND SUGAR.

Starch is very common in vegetables. It is not so common as wood, for that as you have seen is everywhere, in every part of all vegetables from the largest trees to the smallest plants. There is starch in all the vegetable substances we eat. Four-fifths of the flour of which bread is made is starch. Most of the potato is starch. There is much in chestnuts, and even in horse-chestnuts it constitutes one-eighth of the whole. Arrowroot is a starchy meal, prepared from plants that grow in marshy grounds in climates as warm as the East and West Indies. Sago is a starchy substance prepared from the pith of various kinds of palm-trees. From this you see that a large part of the food of man is starch.

Starch can be very readily obtained from wheat flour. Moisten a handful of it with enough water to make a thin paste. Put this into a piece of thick linen cloth and knead it, adding water to the paste as long as the liquid which runs through the cloth appears milky. Let the liquid stand for some time, and a white powder will settle at the bottom. This is wheat starch. What remains in the cloth I will tell you about in the next chapter.

The starch is in grains or granules, and each little grain, as seen by the microscope, has a covering. Now in boiling,

starch swells into a thick jelly. In this operation the coatings of the grains are broken, and the starch absorbs water. This is the reason that rice, beans, barley, etc., swell so much when they are cooked. Chestnuts when boiled swell from the same cause.

You will be surprised to learn that starch, though so different from wood, is composed of the same elements, carbon, hydrogen, and oxygen, and that too in the same proportions. It is deposited in those parts of the plant where it can be used for food, viz., in the grains, seeds, and fruits.

Sugar is another substance found in many plants. All sweet fruits have sugar in them. Besides this, there are some plants which seem designed by the Creator to make sugar for the use of man; of these the principal is the sugar-cane. Then there is the sugar-maple and the sugar-beet. Much sugar is obtained from the sugar-maple in the northern parts of America. On the Continent of Europe, especially in France, the sugar-beet is largely cultivated for the manufacture of sugar.

Sugar, like starch and wood, is composed of carbon, oxygen, and hydrogen, but not in the same proportions. Although we cannot make sugar by mixing these ingredients together, any more than we can wood or starch, yet plants can. The sugar-cane makes sugar out of charcoal and water. Much of the charcoal or carbon is taken from the air by the leaves, while the water comes from the ground by the roots. Long broad leaves, shaped like corn-leaves, by their little and numberless mouths, take in carbon from the air, so that

there may be enough of this material for making sugar. Now as carbon is in the air in part from the breath of animals, probably some of the carbon in the sugar you have eaten may be from somebody's lungs. If so, it went on the wings of the wind to America that the cane-leaf might drink it.

In obtaining sugar from the cane, the juice is pressed out by heavy iron rollers. This juice is then cleared of impurities, and boiled down to such a degree that sugar crystallizes as it cools. While this crystallization takes place a syrup drains off, and this is molasses or treacle. Sugar crystallizes in grains, and is the common brown sugar. Further purification is required to form white sugar.

There are different kinds of sugar. The two most important are grape-sugar and cane-sugar. Grape-sugar is that in grapes and in sweet fruits. Cane-sugar is that in sugar-cane and plants evidently designed by the Creator to manufacture sugar. Cane-sugar has much greater sweetening power than grape-sugar, and therefore is more valuable. It requires almost three teaspoonfuls of grape-sugar to sweeten as much as a single teaspoonful of cane-sugar.

The difference in composition between these two is that grape-sugar has more oxygen and hydrogen than cane-sugar; and as these are added in the proportion required to form water, chemists say that grape-sugar has more water in it than the other.

Though we cannot take carbon, oxygen, and hydrogen, and make them into wood or starch or sugar, we can make sugar out of either starch or wood. What! you will perhaps

exclaim, make sugar out of saw-dust? Yes, exactly so. It can be done by oil of vitriol, water, and heat. Every five pounds of some kinds of wood may be made to give four of sugar.

The process is as follows: Saw-dust is first moistened with a little more than its weight of sulphuric acid or oil of vitriol, and left to stand for about twelve hours. It is now nearly dry; but, on pounding it in a mortar, it becomes liquid. Water is added and it is boiled. Sugar is now formed.

The explanation of its formation is this. In the saw-dust there are certain quantities of carbon, oxygen, and hydrogen. But there is not so much of oxygen and hydrogen as there is in sugar. In order to make the wood into sugar, it is needful to add oxygen and hydrogen, letting the carbon be as it is. This is exactly what sulphuric acid does. It forces some of the water, or oxygen and hydrogen that compose it, to unite with carbon in the saw-dust, and so sugar is made.

But the sugar is not alone, it is a syrup; that is, water is mixed with it. Besides this, sulphuric acid which does not become a part of the sugar is there also. It would not do to let it remain. The way in which it is taken out of the syrup is a good example of chemical affinity. Chalk will take it out. See how it does this. Chalk is carbonate of lime. Now sulphuric acid likes lime better than carbonic acid does. It therefore takes the lime, and carbonic acid flies off. Sulphuric acid forms with lime sulphate of lime or gypsum. As this does not dissolve in water, the syrup is very easily separated.

We now have the syrup. To get the sugar we have only to boil the syrup, and thus drive off the water.

Sugar can be made from rags as easily as from wood; for, as you learned in the previous chapter, rags are nothing but wood in a certain form.

The process of converting starch into sugar is essentially the same, for starch has the same composition as wood, as you learned in the first part of this chapter. But what is the sugar that can thus be made out of such cheap materials as saw-dust and rags? It is not cane-sugar, which is so valuable, but grape-sugar. If we could manufacture cane-sugar in this way, we need not depend so entirely on the sugar-cane for a supply.

I have told you that sugar is in all sweet fruits, but there is not sugar in them at first, they are either tasteless or acid, and become sweet as they ripen. Before they ripen there is starch, which changes into sugar.

Though we can make wood into sugar, we cannot make sugar into wood. This is done, however, by plants. Thus sugar-beet and turnip are sweetest when gathered early; if allowed to grow too long, the sugar is changed into wood, and they become, therefore, tough and tasteless. So, also, if grass be left to grow too long, the starch and sugar in it turn to wood, and the hay is not so sweet and nutritious as it would have been if gathered earlier.

We can make charcoal from sugar, for it is composed of the same elements as wood. We can do it by simply heating the sugar; but a prettier way to do it is this: Put a tablespoonful of strong syrup, made with loaf-sugar, into a

tumbler set in a large plate, and pour upon it a little good sulphuric acid. The acid sets free the charcoal, producing considerable heat. This makes a brisk bubbling up, even over the sides of the tumbler. When the tumbler is cool, pour the contents into the plate, and you have a specimen of *sugar-charcoal.*

CHAPTER XXIX.

GLUTEN.

You see that vegetable substances are made chiefly of carbon, oxygen, and hydrogen; but animal substances, flesh, skin, hair, nerves, etc., are made of the same things, but with another added, viz., nitrogen. It is this gas that makes the great distinction between animal and vegetable substances. Every animal substance has nitrogen in it.

It is nitrogen that gives the peculiar odour we perceive whenever any animal substance is burned. Wood, cotton, linen, etc., cause little smell when burned, but let wool, hair, or leather be burned, and the odour is very marked.

As all substances peculiar to animals have nitrogen, there must be some nitrogen in the food, for if not they would droop and perhaps die. It is the food that makes blood, and blood is the building and repairing material of the body. You see, then, that if no nitrogen is furnished, one of the four great materials for building and repairing will soon be spent. The body, therefore, in a little time, would show this, and get out of repair. To repair the body without nitrogen would be very much like repairing a brick wall without brick, filling up breaches with mortar alone.

Now you can see where some animals get that part of their building and repairing material which we call nitrogen.

Lions, tigers, dogs, cats, etc., eat animal food, and there is always nitrogen in that. But how is it with horses cows sheep, etc.? Where do they get nitrogen? They eat no animal food, and the vegetable substances, wood, starch, and sugar, have no nitrogen in them. There is a plenty of nitrogen in the air, and they continually breathe it. Do they get it in this way? No, not a particle of the nitrogen gas that goes into the lungs gets into the blood. The oxygen that goes into the lungs with the nitrogen enters the blood, but the nitrogen does not. It comes out of the lungs exactly the same as it went in. Neither does a particle of nitrogen go into the body of animals through the skin, though the skin by being surrounded with air, is bathed in it all the time.

How, then, do the vegetable-eating animals get their nitrogen? I will tell you. You remember that, in telling you how to obtain starch from wheat flour, I said that there was a substance left in the linen cloth; it is a substance we call *gluten*—a very glutinous or sticky substance. This portion of flour contains nitrogen. The starchy part is composed of carbon, oxygen, and hydrogen, gluten is composed of these and nitrogen united with them.

It is the gluten of flour that gives firmness to bread. If it were composed of starch alone the bread would be very crumbling. For this reason rice cakes readily break when enough flour is not mingled with the rice. The gluten of flour is needed to hold together the starchy rice.

There is another substance in flour that has nitrogen in it. It is called *albumen,* from the Latin word *albus*, white. It is

like the white of egg, there is but little of it in flour compared with the amount of gluten.

In the grain of wheat then we have three substances, starch, gluten, and albumen. There is much more starch than gluten, the albumen being very small in amount.

There is another substance that has nitrogen in it, which is found in many vegetables. We call it *casein*. It is nearly the same as cheese, which is contained in milk, and makes the curd. This substance is abundant in vegetables that grow in pods, as peas, beans, etc.

The three substances then in vegetables that furnish animals with nitrogen are, gluten, albumen, and casein. They are called *nitrogenous* substances. Gluten is very abundant, especially in grains which are used so extensively for food as wheat, rye, buckwheat, barley, oats, Indian corn, etc.

Starch and sugar have no nitrogen, carbon is their most important element. They are said, therefore, to be *carbonaceous* substances, in distinction from the nitrogenous. Now these substances alone cannot support life for any length of time. Animals would, if fed upon nothing but starch and sugar, languish and die. It would be for want of nitrogen.

There is another class of substances found both in vegetables and animals, which are carbonaceous and have no nitrogen. They are the oils and fats.

The nitrogenous substances in food build and repair the body. Of what use then are starch, sugar, and oils or fats? Their use is chiefly, if not wholly, to continue the heat of

the body. They are part of the fuel, which is burning with the oxygen in the blood, as you learned in the chapter on Animal Heat, page 75.

The power of any particular food to nourish the body or promote its growth is supposed to depend on the amount of nitrogen in it. Rice is not very nutritious, because it contains much starch and little gluten. Wheat, rye, etc., are among the most nutritious vegetables, for they contain much gluten. There is much in the covering of the grains called bran. Peas and beans are nutritious, because they contain much of that nitrogenous substance, casein, or vegetable cheese. Cabbage is a nutritious vegetable, for it has even more gluten in it than the grains; and cauliflower has still more than cabbage.

There is gluten in leaves and grass, but not so much as in grains. The horse, therefore, though he may live upon hay alone when idle, must have some kind of grain when working. The wear and tear of the muscles in working makes a good supply of nitrogenous food necessary for repairs. The giraffe, with his long neck, lives by browsing upon the leaves of trees. But if he worked, like a horse, he would require food richer in gluten.

For the same reason, the food of a labouring man should be richer in gluten than that of a man who lives in idleness. The repairing that his muscles require after labour must be from nitrogen in his food. If the labourer, therefore, should live chiefly on rice, as in China, or on potatoes, as is often the case in Ireland, the machinery of his body would not be well repaired, and he would become weak. He must

have such food as bread and meat, with his potatoes, rice, etc., in order to get nitrogen for growth and repair.

We need the two kinds of food—namely, the one which is for building and the other which is for fuel. For this reason the fuel-food, pork, eats well with the building-food, cabbage.

Those articles in which the two kinds of food are mingled are especially valuable. Thus bread is so valuable that it is called the staff of life. Still better is it when we add the fatty carbonaceous substance, butter. Milk is such a combination of nitrogenous and carbonaceous substances that it is a *complete* food, as shown by the fact that children live a long time on this article alone.

I have told you that all animal substances have nitrogen in them, and that most vegetable substances have not. Still there are vegetable substances that do contain nitrogen. Why do they contain it? For the purpose of supplying it to animals. Animals must have it in their structures—in their muscles, nerves, bones, skin, brain, etc. But vegetables do not need it in their structures. Wood does very well without it, though bone and muscle cannot. As, then, vegetables do not need it in their structures, Providence does not put it there, but into those parts of vegetables which animals use for their food. Hence so much is deposited in various grains.

CHAPTER XXX.

VEGETATION.

Every plant comes from a seed; and when this is put into the ground, a root shoots downward into the earth, and a stalk shoots upward into the air.

Observe how the root and the stalk are made. They are not made as crystals are. Particles are not laid on layer after layer, as in the growth of a crystal. There is no life in a crystal, but there is in a seed. It is this life that forms the plant, and it has its own way of doing so. As the stalk and root are built, channels or tubes are formed along them as it works along; there are no such tubes in a crystal.

Through these tubes sap goes to every part of the plant. This is true of every plant, from the smallest to the largest. Look at a very large and high tree. The life in a little seed began that. It pushed up the stalk a little higher and higher, making tubes in it all the while; and now that it reaches so high, sap goes along these tubes from the very ends of the roots to the very ends of the leaves.

Let us see of what the seed from which all this comes is composed. It is chiefly starch and gluten. Now these substances are insoluble. Of what use, then, can they be in growth when they cannot circulate in the tubes? Unless they be rendered soluble they must remain in the seed.

But the required change is produced in them. As a seed becomes moist, oxygen is absorbed, and thus gluten is made soluble, and the starch changed into sugar, which you know is soluble. So as fast as channels are made in the upshooting plant, sap, with dissolved gluten and sugar circulates in them.

When the little root is formed, and the stalk reaches the air and puts out leaves, the seed may be said to have passed away, its gluten and starch are exhausted. The plant now gathers all its materials for growth from the soil and the air. These are carbon, oxygen, hydrogen, and some nitrogen. As you have learned, it obtains from the air carbon, taking it in at every pore in the leaves. Oxygen and hydrogen are obtained from the water that enters the roots.

From whence comes the nitrogen? It will require much if it be a plant that has gluten in the fruit or seeds.

There is nitrogen all around plants, for four-fifths of the air is nitrogen. But, though the leaves are bathed in it, though it is at the very mouth, as we may say, of every little pore, yet not a particle enters. All the nitrogen which the plant gets comes through the roots. There are various substances in the soil that supply it. One is ammonia, which, you learned on page 85, is composed of nitrogen and hydrogen. This substance abounds in some manures, especially in guano.

You see that carbon, oxygen, hydrogen, and nitrogen are the four grand ingredients in vegetables or plants, also that the three first of these compose the framework, the structure.

There is no nitrogen in woody fibre, it is found only in some fruits and juices. It is put there as a part of the food of animals. Plants gather nitrogen from the earth, and deposit it within their fruits and juices for the use of man and other animals. It is deposited just where wanted. For example, none is lodged in the stalk of wheat, but it is in the seed or grain, so that we have it in the flour with which we make bread.

Besides these things, silica or flint is in the stalks of grain and spires of grass (page 134). In many vegetables, as mustard and onion, there is sulphur. Then there are phosphorus, lime, potash, iron, etc. All these are carried in the sap through the channels of which I told you in the first part of this chapter.

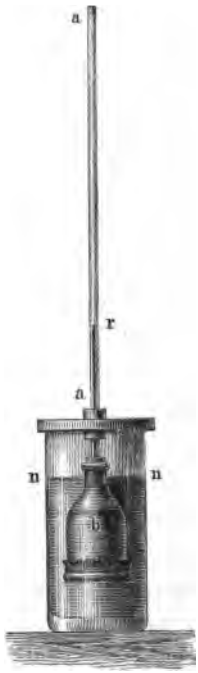
Perhaps you have thought how strange it is that sap should go *up* plants; although there are the little tubes, and although on page 64 you learnt that water owing to capillary attraction rose a short distance, yet that is very different from the sap ascending a tree.

In Fig. 46 is shown the way to make an experiment, about which you may at a future day learn more than at this time. (b) is a glass receiver, having the lower opening covered with some substance such as a piece of bladder. By means of a cork a long tube (a, a) is placed in the receiver. A funnel would make a very good receiver (b).

Fill the receiver (b) with a syrup made of sugar and water. Place the whole as shown in Fig. 46, in a glass (n, n) of water. In a few hours you will find that the height of the liquid in the tube rises as shown at (r).

We do not know the reason of this, but we conclude that by the influence of such a law sap rises in plants. Philosophers have given the name of *endosmose* to the property which this experiment illustrates.

Fig. 46.



Now think what sap is. It is chiefly water, having dissolved in it the various substances mentioned as being in plants. Water, then, not only furnishes the plant with oxygen and hydrogen, but is the means by which other substances needed by the plant are carried in its channels or tubes to the very ends of the leaves. Some of the water remains in the plant, giving its oxygen and hydrogen to it to help to form wood, starch, gluten, sugar, etc. But the largest part of it is breathed into the air through the little pores of the leaves.

The quantity of water that passes from the roots through the channels in plants is much greater than most people suppose. We can get some idea of this by ascertaining how much passes from the leaves. Some experiments have been tried in regard to this, and it was found that a single cabbage breathed from its leaves into the air, in the course of twenty-four hours, nearly a quart of water. If so much comes from a cabbage, how much must all the leaves of a huge tree throw out into the air!

In all juicy fruits there is much water. In the watermelon there is so much that it gives a name to the fruit. It is almost all water with a little sugar dissolved in it. The cells containing this juice are really wood, but very delicate, even more so than those of the orange (page 168).

It is the water in leaves and flowers that gives them softness. You know how stiff the leaves of flowers are when pressed and dried by the botanist in his herbarium; it is because the water is gone from their cells.

You must have noticed how readily the stalks of grass and grain bend before the wind, and then rise, giving the wavy motion so beautiful in a field of grain. This is because there is much water in the cells and channels of the stalks; when however the stalks of grain are dry, as you see in straw, they cannot be so bent.

Wood freshly cut is said to be green; that is, full of sap, hence there is much water in the wood. This prevents its burning well; but if left in the air, the water passes off, and therefore the wood becomes dry.

When wood is burned there are ashes. These are of small bulk compared with the wood. There is only a pound or two of ashes from a hundred pounds of wood. What has become of the remaining ninety-eight pounds of wood? It has passed into the air. In Chapter XXVII. you learnt that a large part of the wood is from the air, so most of it in burning returns to the air. The water passes off in vapour, and most of the carbon of the wood uniting with oxygen, flies off as carbonic acid gas. If this were all, the smoke would not be visible, for you cannot see either vapour or

carbonic acid gas; but there are little particles of carbon, and these form the smoke you can see.

What is really the composition of ashes? They are composed of potash, silica, lime, iron-rust, etc. These substances are found in different proportions in the ashes of different plants. Thus there is more of silica in the ashes of straw than in those of common wood. There is much potash in the ashes of wood, hence the use of them in making soap, as noticed on page 118.

Let us examine more closely what plants get from the ground to make them grow, and how they do it. They get all except carbon. Most of this is from the air, but a little is from the ground. They get from the ground all the oxygen, hydrogen, and nitrogen, part of the carbon, and small quantities of various things they need in addition, such as potash, lime, iron, sulphur, phosphorus, etc.

These ingredients are chiefly from the decay of plants. Every year dead leaves and plants become a part of the earth, and help to form the plants of another year. Barren sand may be made good rich earth by mingling with it decayed or decaying vegetable substances. If, in a garden, there is a pit into which weeds and small trimmings from trees are thrown you can dig from it in two years of time the richest kind of earth, the produce of decayed vegetable matter, which can be used to assist in the formation of other vegetables.

Thus decay and death furnish materials for new life. The living beauty that gladdens our eyes in spring comes, to a great extent, from what fell to the ground and died in

previous years; and not only so, but that which at one time is putrefying, becomes a plant which, with its leaves and flowers, so delights the eyes, and supplies fruits, which are so pleasant to the taste. Nitrogen, one of the ingredients of the ammonia so strong in manure, goes up the channels of wheat-stalks helping to make the gluten of the grain, and as you eat this in bread it forms part of the substance of your body.

You see that there are few ingredients of plants, chiefly four, carbon, oxygen, hydrogen, and nitrogen; but from these, with now and then a little of some others, is formed a great variety of substances. I will notice a few of them.

Some are composed of only two of the chief ingredients of plants, carbon, and hydrogen. To this class belong the oils of orange-peel, lemon, and pepper. The oil of turpentine is also one, and that very singular substance so much used now, caoutchouc, or India-rubber.

Then there are some oils that are composed of three of the four grand ingredients of plants, viz., carbon, oxygen, and hydrogen. Among these are the oils of peppermint, valerian, anise, orange-flowers, rose-petals, etc. Camphor, also, is composed of these three ingredients.

Some oils have a large quantity of sulphur in them, as oil of mustard, onion, asafetida, etc. You know that if a silver spoon be left in mustard it becomes dark-coloured. This is because the sulphur in the mustard unites with the silver to form a sulphide of silver.

There are various acids in vegetables. These are composed of carbon, oxygen, and hydrogen, in different pro-

portions. Some of these have been noticed in the chapter on acids, as *tartaric*, the peculiar acid of grapes; and *malic*, the peculiar acid of apples, pears, and other fruits. The only difference in composition between these two acids is, that tartaric acid has a little more oxygen than malic acid (see page 110).

There are different colouring substances in vegetables, as indigo, the colouring matter of logwood, etc. Like the acids, they are composed of carbon, oxygen, and hydrogen, or of these with nitrogen.

There are many other interesting classes of substances brought to light of late years by chemists, and which they obtain from plants by means you can understand at some future time.

CHAPTER XXXI.

CHEMISTRY OF ANIMALS.

Blood is to an animal what sap is to a vegetable. Sap is water, having dissolved in it whatever is necessary to the growth or building up of the plant; and blood is water, having dissolved in it whatever is necessary to the growth or building up of the animal.

About four-fifths of the blood in man is water; that is, in every five pounds of blood there are four of water. Perhaps you are asking what substances are dissolved in this; that is, what make up the other fifth of the blood. They are carbon, oxygen, hydrogen, nitrogen, chlorine, sodium, potassium, magnesium, iron, phosphorus, and sulphur.

These, you see, are elements, not compounds. They do not however appear as elements in blood. They are united in various ways. For example, iron is united with oxygen, forming oxide of iron, some of this oxide is united with phosphoric acid, making phosphate of iron. So most of the chlorine is united with the metal sodium, forming common salt, giving to blood a saltish taste. Then we have phosphorus, oxygen, and calcium united forming phosphate of lime, of which you learned, on page 131, there is much in bones. About one-third of the blood which is not water is

albumen. This is the same as white of egg, or the albumen which you learned, on page 176, is found in many vegetables; it is composed of the four grand elements, carbon, oxygen, hydrogen, and nitrogen.

Now how do all these substances get into the blood? Chiefly from the food we eat. That part of the food which will nourish the body is drunk in by little pores in the stomach, put into the blood and made a part of it. It is as little mouths in the roots of a plant drink in from the earth what is proper to go into the sap. Thus the root of a plant and the stomach of an animal perform similar duties.

But all substances that are in blood are not always in food. How is it, then, that blood is always supplied with them? It is because food contains that from which these substances are made. There is some chemistry done in the stomach, it is a chemical laboratory, for great chemical changes are produced there. For instance, you eat perhaps much sugar; but there is no sugar in the blood. How is this? Is this sugar lost? No; it is used, but it does not enter the blood as sugar; it helps to make other things.

There is salt in blood, and there is salt in food. Here we have a substance that is not altered by the chemistry of the stomach, as sugar is, but enters the blood as salt.

There is one substance, all of which does not get into the blood from the food; part of it enters by the lungs as we breathe. This is oxygen, the lung-food that I told you about on page 7.

All the parts of the body are made out of blood.

For this purpose the blood, containing the different substances mentioned, circulates everywhere in the body; and materials required for building are used just where wanted. For example, where it is necessary to make bone, materials for bone are taken from the blood, and arranged so as to make bones of the right shape. Phosphate of lime is one of these materials, as I told you on page 133. This is in the blood, ready for use.

So, where nerve is to be made, those materials are taken from the blood of which nerve is composed; and the same is true of all other parts of the body.

Sulphur and silica, or flint, mingled with other ingredients, are in hair, feathers, bone, and nails.

Iron is in blood. It is in a substance that gives the red colour to this fluid. Very little of it is found in the solid parts of the body. None is in the nerves, though persons who have much firmness of character are said to have iron nerves. There is a very little in the hair, helping, with silica or flint, to give it strength. Of what use it is in the blood we do not know. When persons are pale and weak they have not enough of it in the blood, and therefore we give medicines that have iron in them.

You see what a variety of substances there is in blood. Now when different sorts of food are eaten, it is easy to see how all these substances are furnished to the blood. But how is it with a child who lives upon milk? Can there be mingled in that white fluid all the substances I have mentioned? If they were not, there would be something missing in the building up of the body. If, for example,

there were no phosphate of lime in milk, the bones of an infant living on milk would be soft, and bend very easily, for it is the phosphate of lime that makes them hard and stiff. Milk contains all substances required for the growth of the body. It contains all the nutritious substances which can be gathered from meats and vegetables. Milk is made from blood, and blood is made from milk, and they are only two different forms of the same ingredients. The milk of a cow is made from her blood by a chemistry which we do not understand, and when we take it into our stomachs the chemistry there reconverts it into blood. How the iron is in the milk, and is prevented from colouring it red, as it does the blood, we do not know.

No matter how many different articles we eat, the nutritious part of them all, when taken and put into the blood, is a whitish fluid very much like milk; it is called chyle. This fluid is separated or extracted from meat, potatoes, rice, turnips, cabbages, etc., etc.; and it contains all that is needed to form bones, teeth, brain, skin, nerves, muscles, nails, hair, etc., with one single exception—I mean the oxygen which it gets from air in the lungs. Chyle in the blood goes to the lungs to receive a supply of oxygen; and then it becomes a part of the blood, and is suitable for nourishing the body.

CHAPTER XXXII.

CONCLUDING OBSERVATIONS.

It may be well, in this concluding chapter, to look back a little upon the ground over which we have been travelling.

The world is built chiefly out of a few elements. I have told you, in Chapter XIV., that there are about sixty elements, and of these fifty are called metals. Most of them exist in small quantities. A few are very abundant, as iron, calcium, sodium, aluminum, copper, lead, etc. But the most abundant substances in the world are not metals. They are oxygen, carbon, nitrogen, hydrogen, silicon, sulphur, chlorine, etc. Nearly, if not quite one-half of the world is a gas, oxygen, and the four grand elements used in the making the earth are oxygen, carbon, hydrogen, and nitrogen. Three of these are gases. Water, that liquid which is everywhere and in almost everything, is composed of two of them. All living substances, vegetable and animal, are essentially composed either of three of them or of the whole four.

One special and peculiar property of oxygen is that it forms combinations with all the elements. With most of them it unites very readily, with some eagerly; but there are others, as gold, silver, etc., with which it will not unite unless it be forced to do so, as you learned in Chapter IV., and when they are united the bond is so slight that it readily separates.

Let us look at a few of the combinations which oxygen forms. It forms with hydrogen the most abundant of all compounds, water. Mixed with nitrogen and carbonic acid gas, it forms the most abundant of all mixtures, the atmosphere. It forms, with the metals, "oxides," a very numerous class of substances. It forms acids with nitrogen, sulphur, phosphorus, chlorine, silicon, etc. That singular acid, silica, is one of the most plentiful hard substances in the earth, being in granite and many other rocks, and constituting, for the most part, all the sand and a large portion even of the fertile earth. Then we have oxygen in all potash, lime, and their carbonates; carbonates of lime in the forms of limestone, chalk, and marble, being very abundant, sometimes forming even mountains. Oxygen is also a chief ingredient in living substances.

The importance of this element is seen not only in its abundance, but also in its activity. It is no laggard in chemical movements. It is the grand supporter of combustion. It keeps every fire and light burning, and the quick explosions of gunpowder and many other substances are consequent upon its presence. It maintains the life of all animals by entering the lungs, and conveys away carbon from their bodies to the leaves of plants by uniting with it to form carbonic acid gas. It rusts metals, and has such an affinity for some of them that they are never found except in union with oxygen.

Changes in matter from solid to gaseous or liquid, and the reverse—changes in which oxygen is busy—are very wonderful. Thus, in burning wood, the oxygen of the air

unites with the carbon and hydrogen of the solid wood, forming carbonic acid gas and water, which flies off with the gas in vapour. In one hundred pounds of wood, as I have told you already, we have about two pounds of ashes. The ninety-eight pounds, which are water and carbonic acid gas, have passed into the air. What becomes of them? Let us see. Water gathers in the clouds to fall to the earth, or settles upon the grass in the form of dew. There it goes to work again, some of it finds its way into the roots of plants, helping to form their substance by combining with carbon and nitrogen. That part of the ninety-eight pounds which is carbonic acid gas is drunk up by leaves, in order that by chemical operations it may furnish carbon to the plants and trees. The oxygen that has thus conveyed, as we may say, carbon to leaves, returns again in the air to the lungs of animals. Some of the carbon thus furnished to plants comes back also to animals in the food which they eat, to perform again its chemical work.

Many other examples of changes of matter from one form to another might be given, but this must for the present suffice.

When a solid becomes a gas, or a gas a solid, the change is a very great one. When a solid becomes a gas it occupies a larger space, and the particles must therefore be much farther apart. When this change of bulk takes place suddenly, a great effect is produced, as for example in the explosion of gunpowder. On the other hand, when a gas becomes a solid there is great condensation, or, in other words, the particles of the substance are brought much

nearer together. For example, when oxygen unites with iron, and thus becomes a part of a solid substance, about twenty gallons of the gas are pressed, as we may say, into the small space occupied by a pound of the rust (page 81). The same great change in bulk takes place when the carbon in the carbonic acid of the air, taken in by the leaves of a tree, becomes so condensed as to form a part of the solid wood.

In some of the changes in matter there is a very fine division of particles. As you see charcoal burning, solid carbon is passing into the air united with oxygen. The particles of the carbon you see in the solid charcoal, but when they pass off you do not see them. Why? Because they are so finely divided. The division is so fine that not even the microscope can show them. So, also, if you examine grass which feels very rough from the silica or flint that is on its surface, you cannot find any particles of silica in the sap; but they are there, for thus the flint goes from the ground to get to the surface of the grass. Sap is smooth and limpid, for the flint in it is exceedingly fine, and its particles are wide apart; but, deposited in the coating of grass, the flint is rough, and scratches your finger, for the particles are there closely united. So, too, the small quantity of iron that is in blood is very finely divided, its particles being diffused evenly throughout that fluid as it circulates in the arteries and veins.

In the course of this book I have often spoken of the difference between compounds and the ingredients of which they are formed. Thus oxygen, the gas that assists things to

burn, unites with another gas that itself burns, forming a substance—water—which quenches burning. Water also is unlike its components in other respects. It is a heavy fluid, while one of its components, oxygen, is nearly as light as air, and the other, hydrogen, is the lightest substance known. So, also, that powerful liquid, nitric acid, is unlike the oxygen and nitrogen gases that compose it. Take another example of a different character. Phosphorus is a very inflammable substance, and lime is a biting caustic; but phosphoric acid, composed of phosphorus and oxygen, when united with lime, forms phosphate of lime, the mineral matter in our bones. We have one of the most striking examples in common salt, which is composed of a gas which, if breathed, would kill you by suffocation, and a metal that combines very energetically with the oxygen of water.

I have occasionally noticed the fact that a substance may appear in forms, very unlike each other. Thus carbonate of lime appears in the forms of chalk, common limestone, and pure crystallized marble. Gypsum, or plaster of Paris, presents several forms, some of which are very beautiful. Carbon is a wonderful example, for nothing can be more unlike than charcoal, blacklead, and the diamond. There is no substance, perhaps, that appears in so large a number of different forms as wood, as you learned in Chapter XXVII. All this variation in form seems due to variation in the arrangement of the particles, as the proportions of the ingredients are not varied.

In this variation, differences in character are much increased if the proportions of the ingredients are varied.

You know how different calomel and corrosive sublimate are, yet they are made of the same elements, chlorine and mercury, but in different proportions. The five compounds of oxygen and nitrogen are very different from each other, the contrast between the exhilarating gas and nitric acid being remarkably great. But the most wonderful examples are furnished by the chemistry of life. Wood, starch, gum, sugar, oils, perfumes, colouring matters, poisons, etc., how unlike, and yet they are all made of three elements, a solid and two gases. The same may be said of the variety of compound substances in animals. Thus the Creator shows, in the chemistry of life, the greatest power in producing so much variety from so few materials.

The frame-work, as we may call it, of chemistry is quite simple. Most of it may be thus marked out:

Oxygen forms with the metals *oxides*. Oxygen forms with carbon, sulphur, nitrogen, phosphorus, chlorine, etc., *acids*.	These, uniting together, form *salts*.

Sulphur forms with the metals *sulphurets*, or *sulphides*.

Chlorine, iodine, etc., form with the metals *chlorides*, *iodides*, etc.

Then, in the chemistry of life:

Some vegetable substances are made of *oxygen*, *carbon*, and *hydrogen*.

Other vegetable substances, And all animal substances,	are made of *oxygen*, *carbon*, *hydrogen*, and *nitrogen*.

There are some substances not included in this plan.

Such, for example is water, and yet it has a great deal to do with chemical operations.

This leads me to remark that much of the matter in the world is constantly circulating between animals, vegetables, and the earth, and in this circulation ever changing. The grand means by which the circulation is carried on are air and water, which are everywhere in motion, conveying many substances to distant places. For example, air takes carbon from our lungs, and carries it aloft for the leaves, bringing back to our lungs the oxygen that the leaves breathe out. As an example of the agency of water in this circulation, you have seen how it dissolves carbonate of lime from the rocks and earth (Chapter XXI.), carrying it into the sea that some animals may construct their shells. So, also, water brings silica to grasses and grains, that it may be sucked up by the roots. In these and many other ways, air and water are ever busy, circulating in every direction solid as well as liquid and gaseous substances; and they thus have more influence than any other agents in carrying on the grand chemical operations of the world. They are not only continually changing, but also enabling other substances to change.

The world, as you have seen, is emphatically a world of change; and in the changes that take place there is no loss, no destruction. When things burn, as we express it, there is no destruction, there is merely change from one form to another, and what seems to vanish, soon reappears in solid forms that are growing up around us. So, when decay takes place, there is no loss of a single particle of matter, there

are only chemical changes forming new combinations and arrangements of the particles of the decaying substance. Chemistry is at work everywhere, not destroying, but taking to pieces only to rebuild again, and it does the latter quite as readily and rapidly as it does the former.

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CATENA CLASSICORUM—continued.

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CATENA CLASSICORUM—continued.

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HERODOTI HISTORIA.

By H. G. WOODS, M.A., *Fellow and Tutor of Trinity College, Oxford.*

Book I., 6*s.*   Book II., 5*s.*

[*Just published.*

Give every man thy ear, but few thy voice;
Take each man's censure, but reserve thy judgment.
Costly thy habit as thy purse can buy,
But not express'd in fancy; rich, not gaudy;
For the apparel oft proclaims the man;
And they in France of the best rank and station
Are of a most select and generous chief in that.
Neither a borrower nor a lender be;
For loan oft loses both itself and friend,
And borrowing dulls the edge of husbandry.
This above all: to thine ownself be true,

---

68 *Give every man thine ear.* For a good listener is generally thought by the willing speaker to be a man of sound judgment. "Mr. Canning," says Sir E. Bulwer, "would often make a kind of lounging tour of the House, listening to the tone of the observations which the previous debate had excited; so that at last, when he rose to speak, he seemed to a large part of his audience to be merely giving a more striking form to their own thoughts."

71 *Express'd in fancy.* Not marked or singular in device; but with a quiet costliness suggestive of habitual self-respect.

74 *A most select and generous chief.* Are of a most noble device in this—the 'chief' being the upper part of a heraldic shield. The passage is strangely misunderstood and even altered by Delius, Elze, and other editors. As regards the metre, the three first syllables of the line must be pronounced rapidly in the time of one, as in Macbeth, i. 5, we have:

"And take my milk for gall, you murdering ministers."

76 *Loses itself and friend.* Who ever loves the creditor whom he cannot pay?

77 *Dulls the edge of husbandry.* Takes the edge off economy. Money borrowed, whether by individuals or nations, represents no saving or self-denial, and is therefore lightly parted with.

78 *To thine ownself be true.* As you inwardly resolve, so do: then faithfulness to others as well as yourself becomes the habit of your soul. So Wordsworth (v. 49) speaks of the same steadfastness in—

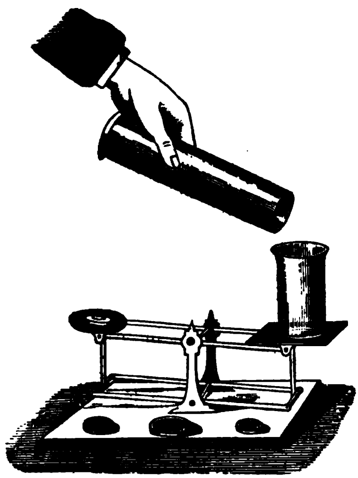
"The generous spirit who when brought
Amongst the tasks of real life, has wrought
Upon the plan that pleased his childish thought."

And, in an equally noble style, an Eastern sage has said, "There is one way to gladden those whom you love: if one is not upright when retired into himself, never will he bring rejoicing to those who are near him."

[*Select Plays of Shakspere. See page* 4.]

In Fig. 16 is represented a very pretty experiment, showing that this gas is heavier than air. First, balance a jar with a weight. I say *balance* a jar. Is that exactly correct? Is there not something in the jar? "No," you will perhaps say, "it is empty." But think a moment. That jar is full of something, and that something has weight. It is full of air. We have balanced, then, a jar full of air. Now if, as represented, carbonic acid gas be poured into the jar on the scales, the jar will descend and the weight will rise. Why? Because there is now a gas in the jar that is heavier than air.

Fig. 16.

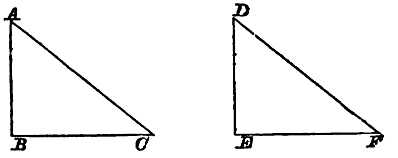


If you have a jar filled with this gas, you can take it out with a little bucket, as seen in Fig. 17. As you take one bucketful after another out, it can be poured away as water; and air will take the place of the gas as fast as it is removed.

If a soap-bubble fall into a jar of carbonic acid gas, it will not go to the bottom as it would if the jar were full of air. It will descend a little into the jar, and then ascend and remain in its open mouth. Why is this? The air that is blown into the bubble is lighter than the gas in the jar,

PROPOSITION B. THEOREM.

If two triangles have two angles of the one equal to two angles of the other, each to each, and the sides adjacent to the equal angles in each also equal; then must the triangles be equal in all respects.



In $\triangle$s ABC, DEF,

let $\angle ABC = \angle DEF$, and $\angle ACB = \angle DFE$, and $BC = EF$.

Then must $AB = DE$, *and* $AC = DF$, *and* $\angle BAC = \angle EDF$.

For if $\triangle DEF$ be applied to $\triangle ABC$, so that E coincides with B, and EF falls on BC;

then $\because EF = BC$, $\therefore F$ will coincide with C;

and $\because \angle DEF = \angle ABC$, $\therefore ED$ will fall on BA;

$\therefore D$ will fall on BA or BA produced.

Again, $\because \angle DFE = \angle ACB$, $\therefore FD$ will fall on CA;

$\therefore D$ will fall on CA or CA produced.

$\therefore D$ must coincide with A, the only pt. common to BA and CA.

$\therefore DE$ will coincide with and $\therefore$ is equal to AB,

and DF .... AC,

and $\angle EDF$ .... $\angle BAC$;

and $\therefore$ the triangles are equal in all respects. Q. E. D.

COR. Hence, by a process like that in Prop. A, we can prove the following theorem:

If two angles of a triangle be equal, the sides which subtend them are also equal. (Eucl. I. 6.)

thus: if the articles had cost £1 each, the total cost would have been £2478;

∴ as they cost $\frac{1}{6}$ of £1 each, the cost will be £$\frac{2478}{6}$, or £413.

The process may be written thus:

3*s.* 4*d.* is $\frac{1}{6}$ of £1	£2478 = cost of the articles at £1 each.
	£413 = cost .... at 3*s.* 4*d.* ...

Ex. (2). Find the cost of 2897 articles at £2. 12*s.* 9*d.* each.

£2 is 2 × £1	2897 . 0 . 0 = cost at £1 each.
10*s.* is $\frac{1}{2}$ of £1	5794 . 0 . 0 = ... £2 ....
2*s.* is $\frac{1}{5}$ of 10*s.*	1448 . 10 . 0 = ... 10*s.* ....
8*d.* is $\frac{1}{3}$ of 2*s.*	289 . 14 . 0 = ... 2*s.* ....
1*d.* is $\frac{1}{8}$ of 8*d.*	96 . 11 . 4 = ... 8*d.* ....
	12 . 1 . 5 = ... 1*d.* ....
	£7640 . 16 . 9 = ... £2. 12*s.* 9*d.* each.

NOTE.—A shorter method would be to take the parts thus:

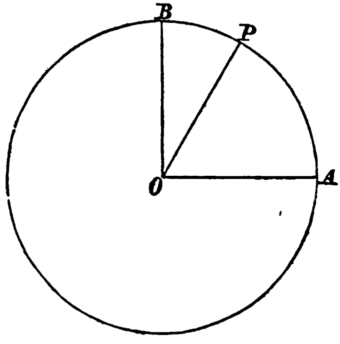
10*s.* = $\frac{1}{2}$ of £1; 2*s.* 6*d.* = $\frac{1}{4}$ of 10*s.*; 3*d.* = $\frac{1}{10}$ of 2*s.* 6*d.*

Ex. (3). Find the cost of 425 articles at £2. 18*s.* 4*d.* each.

Since £2. 18*s.* 4*d.* is the difference between £3 and 1*s.* 8*d.* (which is $\frac{1}{12}$ of £1), the shortest course is to find the cost at £3 each, and to *subtract from it* the cost at 1*s.* 8*d.* each, thus:

	£ . *s.* . *d.*
£3 is 3 × £1	425 . 0 . 0 = cost at £1 each.
1*s.* 8*d.* is $\frac{1}{12}$ of £1	1275 . 0 . 0 = ... £3 ....
	35 . 8 . 4 = ... 1*s.* 8*d.* each.
	£1239 . 11 . 8 = ... £2. 18*s.* 4*d.* each.

28. ***To shew that the angle subtended at the centre of a circle by an arc equal to the radius of the circle is the same for all circles.***



Let O be the centre of a circle, whose radius is r;

AB the arc of a quadrant, and therefore AOB a right angle;

AP an arc equal to the radius AO.

Then, $AP = r$ and $AB = \frac{\pi r}{2}$. (Art. 14.)

Now, by Euc. VI. 33,

$$\frac{\text{angle } AOP}{\text{angle } AOB} = \frac{\text{arc } AP}{\text{arc } AB},$$

or,

$$\frac{\text{angle } AOP}{\text{a right angle}} = \frac{r}{\frac{\pi r}{2}}$$

$$= \frac{2r}{\pi r}$$

$$= \frac{2}{\pi}.$$

Hence

$$\text{angle } AOP = \frac{2 \text{ right angles}}{\pi}.$$

Thus the magnitude of the angle AOP is independent of r and is therefore the same for all circles.

[*Trigonometry. See page* 8.]

89. CASE II. **The next case in point of simplicity is that in which four terms can be so arranged, that the first two have a common factor and the last two have a common factor.**

Thus

$$\begin{aligned} x^2+ax+bx+ab &= (x^2+ax)+(bx+ab) \\ &= x(x+a)+b(x+a) \\ &= (x+b)(x+a). \end{aligned}$$

Again

$$\begin{aligned} ac-ad-bc+bd &= (ac-ad)-(bc-bd) \\ &= a(c-d)-b(c-d) \\ &= (a-b)(c-d). \end{aligned}$$

EXAMPLES.—XVIII.

Resolve into factors:

1. $x^2-ax-bx+ab$.
2. $ab+ax-bx-x^2$.
3. $bc+by-cy-y^2$.
4. $bm+mn+ab+an$.
5. $abx^2-axy+bxy-y^2$.
6. $abx-aby+cdx-cdy$.
7. $cdx^2+dmxy-cnxy-mny^2$.
8. $abcx-b^2dx-acdy+bd^2y$.

90. Before reading the Articles that follow the student is advised to turn back to Art. 56, and to observe the manner in which the operation of multiplying a binomial by a binomial produces a *trinomial* in the Examples there given. He will then be prepared to expect that in certain cases a *trinomial can be resolved into two binomial factors*, examples of which we shall now give.

91. CASE III. To find the factors of

$$x^2+7x+12.$$

Our object is to find two numbers whose product is 12,
and whose sum is 7.

These will evidently be 4 and 3,

$$\therefore x^2+7x+12=(x+4)(x+3).$$

Again, to find the factors of

$$x^2+5bx+6b^2.$$

Our object is to find two numbers whose product is $6b^2$,
and whose sum is $5b$.

These will clearly be $3b$ and $2b$,

$$\therefore x^2+5bx+6b^2=(x+3b)(x+2b).$$

Praetexta et trabeae, fasces, lectica, tribunal.
Quid, si vidisset praetorem curribus altis
Exstantem et medio sublimem in pulvere Circi,
In tunica Jovis, et pictae Sarrana ferentem
Ex humeris aulaea togae, magnaeque coronae
Tantum orbem, quanto cervix non sufficit ulla?
Quippe tenet sudans hanc publicus, et, sibi Consul
Ne placeat, curru servus portatur eodem.
Da nunc et volucrem, sceptro quae surgit eburno,
Illinc cornicines, hinc praecedentia longi
Agminis officia et niveos ad fraena Quirites,
Defossa in loculis quos sportula fecit amicos.
Tum quoque materiam risus invenit ad omnes
Occursus hominum, cujus prudentia monstrat
Summos posse viros et magna exempla daturos
Vervecum in patria crassoque sub aere nasci.

35] These details are mentioned not as more ridiculous in themselves than anything Democritus had seen in Greece, but because Democritus regarded all human life as a farce, and at Rome the farce was more elaborate. *Lectica* refers to the procession of clients who accompanied it; *tribunal* to the display of empty eloquence before it.

36, sqq.] "What would he have said of the praetor's triumphal procession from the Capitol to the Circus?" The triumphal dress suggests the idea of triumph, and this *consul* (inf. 41).

38 **tunica Jovis**] Whom he personated, hence the eagle on his sceptre. The tunic was so costly that it was not till the third century that a private person possessed one of his own, even the emperors when they triumphed supplied themselves from the treasury of the Capitol or of the Palace.

— **Sarrana**] From the unhellenized form of Tyrus.

39 **aulaea**] A whole stage-curtain of a toga.

41 **Quippe**] "No head could support it: why it makes the slave sweat to hold it up."

44 **longi agminis officia**] There is no more difference between this and longa agmina officiosorum, than between 'a high-spirited nobleman on a long-tailed horse,' and 'a long-tailed nobleman on a high-spirited horse.'

45 **niveos**] In bran new togas probably given for the occasion.

46 **Defossa**] To make sure that they've got it: also to make sure that they will not lose it, cf. Fallacem circum, Hor. *Sat.* I. vi. 113.

47 **Tum**] Even between B.C. 460—357.

50] An Abderite would have hung himself. The cord giving way, he fell, and broke his head. He first went to the surgeon, and had his wound plastered, and then again hung himself.

THE ELECTRA OF

ΗΛ. [*interrupting*] ***τί τῶν ἀπόντων ἢ τί τῶν ὄντων πέρι;***
ΠΡ. [*solemnly*] ***λαβεῖν φίλον θησαυρόν, ὃν φαίνει θεός.***
ΗΛ. ***ἰδού, καλῶ θεούς.***
[*clasping her hands*] ***ἢ τί δὴ λέγεις, γέρον;***
ΠΡ. ***βλέψον νυν ἐς τόνδ', ὦ τέκνον, τὸν φίλτατον.***
[*turning her round to* ORESTES.]
ΗΛ. [*sadly*] ***πάλαι δέδοικα, μὴ σύ γ' οὐκέτ' εὖ φρονῇς.***
ΠΡ. ***οὐκ εὖ φρονῶ 'γὼ σὸν κασίγνητον βλέπων;***
ΗΛ. [*starting suddenly*]
πῶς εἶπας, ὦ γεραί', ἀνέλπιστον λόγον;
ΠΡ. [*emphatically*] ***ὁρᾶν Ὀρέστην τόνδε τὸν Ἀγαμέμνονος.***
ΗΛ. ***ποῖον χαρακτῆρ' εἰσιδών, ᾧ πείσομαι;*** [*incredulous*]
ΠΡ. [*pointing at a scar in* ORESTES' *forehead*]
οὐλὴν παρ' ὀφρύν, ἥν ποτ' ἐν πατρός δόμοις
νεβρὸν διώκων σοῦ μέθ' ἠμάχθη πεσών.
ΗΛ. ***πῶς φῄς; ὁρῶ μὲν πτώματος τεκμήριον.***
[*astounded, but still hesitating.*]
ΠΡ. ***ἔπειτα μέλλεις προσπίτνειν τοῖς φιλτάτοις;***
ΗΛ. [*resolved*] ***ἀλλ' οὐκέτ', ὦ γεραιέ· συμβόλοισι γὰρ***
τοῖς σοῖς πέπεισμαι θυμόν. [*she rushes in a transport of joy into her brother's arms.*] ***ὦ χρόνῳ φανείς,***
ἔχω σ' ἀέλπτως. ΟΡ. ***κἀξ ἐμοῦ γ' ἔχει χρόνῳ.***
ΗΛ. ***οὐδέποτε δόξασ'.*** ΟΡ. ***οὐδ' ἐγὼ γὰρ ἤλπισα.***
ΠΡ. ***ἐκεῖνος εἶ σύ;***
ΟΡ. ***σύμμαχός γέ σοι μόνος,***
ἣν ἐκσπάσωμαί γ' ὃν μετέρχομαι βόλον.
πέποιθα δ'. ἢ χρὴ μηκέθ' ἡγεῖσθαι θεούς,
εἰ τἄδικ' ἔσται τῆς δίκης ὑπέρτερα. [*with confidence.*]

[*Scenes from Greek Plays. See page* 18.]

EXERCISE XXII.

HERCULES.

I was born a boy, stronger than brother Iphicles,
a new-born babe worthy of Zeus as father;
and I showed strength, released from swaddling clothes;
and I proved myself to all nobly bred.
Hērā sent on us two two snakes for murder;
and just before dawn flashed down a dreadful light on the bed.
Iphicles seeing monsters weeps in vain,
and silently crouches hidden in bed-clothes;
but I shouted aloud having conquered serpents:
and this is first of contests. And the neighbours
asked, How is Ampĭtryon father of the boy?
for he prevails over hydra and savage lion;
running, not hunting, he catches a stag,

---

1. *I was born,* Ex. v. 8.

2. *New-born,* νεογνὸς.

3. *To release,* ἀπαλλάσσειν.

4. *Proved myself,* aor. pass. of φαίνω. *Bred,* perf. part. Anapæst in first foot, or tribrach in second.

5. *Two,* sign of the dual. *For,* πρὸς.

6. *Just before,* ὑπὸ with the accusative. *To flash down on,* κατασκήπτω.

7. *Monster,* δά'κος. *In vain,* Ex. xvi. 6. Insert μὲν for the sake of contrast with the ninth line, as in Ex. xix. 1.

9. *To shout aloud,* ἀναλαλάζειν.

11. *To ask a question,* ἐρωτᾶν: aorist, ἠρόμην. The three last syllables of Ἀμφιτρύων make an anapest.

12. *To prevail over,* κρατεῖν, with the genitive.

13. *Running,* δρομαῖος. *To hunt* = to be a hunter. static verb from κυνηγέτης. Tribrach in third foot.

[*Iophon. See page* 16 ·

[*Specimen Page, No.* 10.]

their kind, and of every creeping thing of the earth after his kind." Sufficient food was also to be provided: "take thou unto thee of all food that is eaten, and thou shalt gather it to thee, and it shall be for food for thee and for them" [GEN. vi. 19-21].

To make all these preparations required a strong belief in God on the part of Noah. The world around him utterly disbelieved the message which he conveyed to it during many years of preparation as the "preacher of righteousness" [2 PET. ii. 5], while God's longsuffering waited [1 PET. iii. 20]. Our Lord says that "they were eating and drinking, marrying and giving in marriage, until the day that Noah entered into the ark, and knew not until the flood came and took them all away" [MATT. xxiv. 38; LUKE xvii. 26]. But though all the world disregarded, Noah was entitled to be enrolled among the number of St. Paul's "elders who obtained a good report," for his faith made him believe in the things of which God gave him warning "though not seen as yet" [HEB. xi. 7], and it is recorded of him, "Thus did Noah; according to all that God commanded him so did he" [GEN. vi. 22].

The Ark which Noah built in obedience to the Divine command was not a navigable ship, but a great wooden "coffer," or water-tight chest, made so as to float about steadily upon the water.[1]

It was built of cypress or "gopher" wood, and covered with pitch within and without to secure it against leakage from the flood below or the rain above. The size of the ark is distinctly given as being 300 cubits in length by 50 cubits in width, and 30 cubits in height. The cubit is reckoned at about 21 inches, and we are thus able to compare the size of the ark with that of our large iron and wooden ships of modern days.[2]

	Length.	Breadth.	Depth.
The Ark . .	525 feet	87 feet 6 inches	52 feet 6 inches
Duke of Wellington	240 feet	60 feet	72 feet 4 inches
Great Eastern .	680 feet	83 feet	58 feet

[1] Its object being the same as that of the "ark" in which the infant Moses was placed when cast into the Nile in obedience to the edict of Pharaoh.

[2] The proportions of the ark are exactly those of the human body, viz., 10·+1·6+1·; and the capacity of these proportions for stowage has been proved by experiments in Holland and Denmark to be a third greater than that of vessels as built for ordinary sailing purposes. That of the Ark was thus about the same as that of the Great Eastern.

[*Companion to Old Testament.* *See page* 24.]

Twenty-ninth Lesson.

CHANTING.

CHANTING is the arrangement of prose in a rhythmical form. The psalms, canticles, &c. are sung or chanted to melodies called CHANTS, which are either SINGLE or DOUBLE.

The melody of a single chant is, for convenience, written in phrases of seven bars of two minims each or their value.

The first half of a chant has three, the second four bars.

The first half is called the *mediation*, the second the *cadence.*

TURNER.

First half. *Second half.*

A double chant is simply a single chant form repeated.

ATTWOOD.

First half a. *Second half a.* *First half b.* *Second half b.*

A single chant is arranged to fit one verse of the psalms, a double chant two; for the long psalms quadruple chants, of which the phrase or melody is designed to include four verses, have been written.

A changeable chant is one whose key-chord may be either

[*The Chorister's Guide. See page* 28.]

(especially in winter), and only a limited number of troops can march along one road. Thus all roads leading out of a fortress are to some extent like causeways across a marsh, for practical purposes. The difficulty is diminished by acting at night, and by making feints.

24. Fort St. Georges was on the east, La Favorita on the north side, both on the outside of the lakes. A tête-de-chaussée is a fort which commands and "caps" a road, as a tête-de-pont does a bridge.

25. "Considered himself able to obtain."

26. Detached, that is, from the army now under the Archduke Charles. Till this new force, under a new general, should arrive, Melas was left in command of what remained of Beaulieu's army, now in retreat up the valley of the Adige. Beaulieu himself was recalled.

27. The district called the Vorarlberg lies between the Lake of Constance and the Tyrol. The Tyrolese attachment to the House of Austria is famous. In 1809, Napoleon wanted to take the Tyrol from Austria, and give it to Bavaria, setting up the latter as a rival power to Austria. The Tyrolese resisted. [Story of Hofer.]

28. [Why did not Bonaparte cross the Adige, or else ascend it, and make for the Danube ?]

29. "Dependent on" (comp. the English "irrelevant") . . . "invested with," i.e. holding. These little domains were only nominally dependent on the empire; in reality they were part of the territory of Genoa, and contributed to its militia. "The empire" had only eight years more to live. When Francis II. saw that he had lost all real power as emperor, he threw it up altogether, and took the title of Emperor of Austria instead.

30. [St. Januarius.]

31. There were also six thousand English in Corsica, who might have reinforced an army attacking Bonaparte from the south. [Have English troops ever been in North Italy ? Only once, I believe.]

32. In its lower course, the Po is higher than the surrounding country, thanks to the deposits brought down from the Alps, which raise its bed incessantly. It is walled in by high embankments, kept in order by a staff of engineers, as in Holland. But, in spite of their efforts, the river sometimes breaks through.

33. "Referred the question of peace to."

34. Napoleon had strange good fortune in one respect: his enemies never attacked him at the same moment. In this campaign he could hardly have resisted a flank attack from a Papal and Neapolitan army combined with that of the Austrians. So, when he beat Austria at Austerlitz, Prussia on his left flank was holding back; when he beat Prussia at Jena, Austria on his right flank was passive; when he invaded Russia, neither Prussia nor Austria stirred; when at last they did combine in one attack, they were more than a match for him, and he was ruined in the great battle of 1813.

[*Campaigns of Napoleon. See page* 27.]

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